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DETERMINING THE RETURN OF ENERGY EFFICIENCY INVESTMENTS IN DOMESTIC AND DEPLOYED MILITARY INSTALLATIONS

by

Nathan J. Gammache

December 2007

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13. ABSTRACT (maximum 200 words)

The purpose of this research is to determine the return on energy efficiency investments in domestic installations and military forward operating bases. This research considers two current options for increasing energy efficiency at military installations: the use of Energy Savings Performance Contracts to fund energy efficiency improvements at domestic military installations, and the use of waste to energy generators at remote, deployed military installations.

In domestic military installations, energy requirements are provided primarily via external utilities. Energy saving efforts at domestic installations seek to reduce utility expenses by private equity investment in energy efficiency technologies. In remote military installations, generators provide the majority of electricity by burning fossil fuels delivered from fuel convoys. Forward deployed installation energy efficiency can be achieved through expanded on-site use of alternative fuels. By using field waste as a fuel source, the external fuel demand at forward military operating bases may be reduced. Estimated financial returns of these energy efficiency methods are included in the analyses of this research. This research also discusses the governmental policies mandating energy efficiency and explains how involved parties benefit financially from energy efficiency investments.

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DETERMINING THE RETURN OF ENERGY EFFICIENCY INVESTMENTS IN DOMESTIC AND DEPLOYED MILITARY INSTALLATIONS

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ABSTRACT

The purpose of this research is to determine the return on energy efficiency investments in domestic and deployed military installations. This research considers two current options for increasing energy efficiency at military installations: the use of Energy Savings Performance Contracts to fund energy efficiency improvements at domestic military installations, and the use of waste-to-energy generators at deployed military installations.

In domestic military installations, energy requirements are met primarily via external utilities. Energy-saving efforts at domestic installations seek to reduce utility expenses by private equity investment in energy efficient technologies. In deployed military installations, including remote installations and forward military operating bases, generators provide the majority of electricity by burning fossil fuels delivered from fuel convoys. Deployed installation energy efficiency can be achieved through expanded on-site use of alternative fuels. By using field waste as a fuel source, the external fuel demand at deployed installations can be reduced. Estimated financial returns of these energy efficient methods are included in the analysis of this research. This research also discusses governmental policies mandating energy efficiency and explains how involved parties benefit financially from energy efficiency investments.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEPI	Army Environmental Policy Institute
bbl/d	Barrels of oil per day
BTU/gsf	British Thermal Unit per gross square footage
CAA	Clean Air Act
CG, MNF-W	Commanding General, Multi-National Force-West
CO	Carbon Monoxide
CONUS	Continental United States
COTS	Commercial Off the Shelf
CY	Calendar Year
DARPA	Defense Advanced Research Projects Agency
DESC	Defense Energy Support Center
DFSP	Defense Fuel Supply Point
DLA	Defense Logistics Agency
DLSci	Defense Life Sciences LLC
DoD	Department of Defense
DSB	Defense Science Board
DWCF	Defense Working Capital Fund
ECBC	Edgewood Chemical Biological Center
EIA	Energy Information Administration
EO 13423	Executive Order 13423
EPAct 2005	Energy Policy Act of 2005
ESCO	Energy Service Company
ESPC	Energy Savings Performance Contracting/Contracts
FY	Fiscal Year
GAO	Government Accountability Office
GSF	Gross Square Footage
HAPs	Hazardous Air Pollutants
HVAC	Heating, Ventilation, and Air Conditioning
IED	Improvised Explosive Device
IG DoD	Inspector General, Department of Defense
IGA	Investment Grade Audit
JLTV	Joint Light Tactical Vehicle
JP-8	Jet Propellant-8

LCC	Life-cycle Costing
LCCE	Life-cycle Cost Estimate
LMI	Logistics Management Institute
MILCON	Military Construction
MNS	Mission Needs Statement
MOS	Military Occupational Specialty
NAAQS	National Ambient Air Quality Standards
NOX	Nitrogen Oxides
O_3	Ozone
ODUSD (I&E)	Office of Deputy Undersecretary of Defense (Installations and Environment)
OMB	Office of Management and Budget
O&S	Operations and Support (aka O&M, Operations and Maintenance)
OSD	Office of the Secretary of Defense
OSD (PA&E)	Office of the Secretary of Defense (Program Analysis and Evaluation)
Pb	Lead
$PM_{2.5}$	Fine Particulate Matter
PM_{10}	Inhalable Coarse Matter
POD	Point of Debarkation
POE	Point of Embarkation
PPBE	Planning, Programming, Budgeting, Execution System
REF	Rapid Equipping Force
ROI	Return on Investment
SBCT	Stryker Brigade Combat Team
SBIR	Small Business Innovation Research
SME	Subject Matter Expert
SMP	Sustain the Mission Project
SO_2	Sulfur Dioxide
STTR	Small Business Technology Transfer
TACOM	Tank-automotive and Armaments Command
TGER	Tactical Garbage-to-Energy Refinery
UESC	Utility Energy Savings Contracts
USD (AT&L)	Undersecretary of Defense (Acquisition, Technology and Logistics)
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

The purpose of this research is to determine the return on energy efficiency investments in domestic installations and military forward operating bases.

This report considers two current options for increasing energy efficiency:

- at domestic military installations, the use of Energy Savings Performance Contracts (ESPCs) to fund energy efficiency improvements, and
- at military forward operating bases, the use of waste-to-energy generators.

For all domestic government Super ESPCs issued from 1998 to 2007, the government is contracted to save a total of $27 million with the contracts relative to status quo through the term of the contracts. However, during this same period, private lenders will receive the bulk of the utility savings, which is far in excess of government savings. Of the forecasted $2.68 billion in utility savings, $1.09 billion will repay initial project investments leaving $1.59 billion transferred to the private equity lenders as net income. While the government benefits from this arrangement by reducing energy usage and complying with Executive Order 13423, private lenders have significant financial incentives as well. Returns on investment for equity lenders range from 116 to 224 percent over the life of the contract. If the government chose to fund the projects and was able to reproduce the program management and other behaviors of these commercial vendors, it may have realized a $1.59 billion savings after repaying all project investment costs.

In military forward operating bases, a prototype waste-to-energy refinery device that converts common field waste into electrical power is being considered as a means to reduce the delivered fuel demand of remote locations. Recent studies provide estimates of fuel delivery and waste disposal costs that are the foundation for determining the return on investment of such a device. Initial procurement costs and subsequent reductions therein due to learning effects also impact the return on investment. This research considered three fuel burden cost estimates and one burdened waste disposal cost in determining the return on investment (ROI) of a tactical-garbage-to-energy (TGER)

device. Initial procurement cost estimates include current prototype unit costs of $1.3 million and expected production unit costs of $300,000. Return on investment estimates vary as illustrated in Tables 1 and 2. Vertical headings indicate burdened costs as estimated by Logistics Management Institute (LMI), Army Environmental Policy Institute's Sustain the Mission Profile (SMP), and the Office of the Secretary of Defense (Program Analysis and Evaluation) (OSD). Horizontal headings indicate the expected lifecycle of a TGER device. Combinations for positive returns are above the bold line, while negative returns are below the bold line. This report includes an analysis of more complete savings possible from remote military installation energy efficiency.

All dollar figures in FY07K$										
Time Period (Years)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment (initial cost difference)	1,275									
Cumulative LMI Operating Savings	1,284	2,569	3,853	5,137	6,422	7,706	8,990	10,275	11,559	12,843
LMI Model ROI	1%	101%	202%	303%	404%	504%	605%	706%	807%	907%
Cumulative SMP Operating Savings	269	537	806	1,075	1,343	1,612	1,880	2,149	2,418	2,686
SMP Model ROI	-79%	-58%	-37%	-16%	5%	26%	47%	69%	90%	111%
Cumulative OSD Operating Savings	233	465	698	930	1,163	1,395	1,628	1,860	2,093	2,325
OSD Model ROI	-82%	-64%	-45%	-27%	-9%	9%	28%	46%	64%	82%
Cumulative Unburdened Operating Savings	90	180	269	359	449	539	629	719	808	898
Unburdened ROI	-93%	-86%	-79%	-72%	-65%	-58%	-51%	-44%	-37%	-30%

Table 1. Cumulative Operating Savings and Comparative ROIs (TGER @ $1.3)

All dollar figures in FY07K$										
Time Period (Years)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment (initial cost difference)	275									
Cumulative LMI Operating Savings	1,284	2,569	3,853	5,137	6,422	7,706	8,990	10,275	11,559	12,843
LMI Model ROI	367%	834%	1301%	1769%	2236%	2703%	3170%	3637%	4104%	4571%
Cumulative SMP Operating Savings	269	537	806	1,075	1,343	1,612	1,880	2,149	2,418	2,686
SMP Model ROI	-2%	95%	193%	291%	389%	486%	584%	682%	779%	877%
Cumulative OSD Operating Savings	233	465	698	930	1,163	1,395	1,628	1,860	2,093	2,325
OSD Model ROI	-15%	69%	154%	238%	323%	407%	492%	577%	661%	746%
Cumulative Unburdened Operating Savings	90	180	269	359	449	539	629	719	808	898
Unburdened ROI	-67%	-35%	-2%	31%	63%	96%	129%	161%	194%	227%

Table 2. Cumulative Operating Savings and Comparative ROIs (TGER @ $300K)

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I. INTRODUCTION

A. SCOPE AND LIMITATIONS

The purpose of this research is to determine the return on energy efficiency investments in domestic installations and military forward operating bases.

This report considers two current options for increasing energy efficiency at military installations: the use of Energy Savings Performance Contracts (ESPCs) to fund energy efficiency improvements at domestic military installations, and the use of field waste-to-energy generators at remote, deployed military installations.

For domestic installations, savings from energy efficiency are the result of reduced utility usage as measured by utility bills. The amount of utility savings possible determines the amount of capital available for investment in energy efficiency improvements. The selection process for determining energy savings potential, the availability of investment capital, and presidential requirements to reduce energy intensity, are the focus of domestic energy efficiency investments in this report.

In assessing the return on energy efficiency investments at remote, deployed installations, the reduction in total costs as a result of the investment provides a more complete savings return. Direct fuel offsets of implementing a field waste-to-energy generator provide savings in excess of the cost of the fuel displaced. Reduced waste disposal costs, reduced fuel logistics costs, and reduced security concerns contribute to the direct fuel offset savings to provide a more complete analysis of the value of energy efficiency. This research includes an analysis of more complete savings possible from remote military installation energy efficiency.

B. ENERGY USE BY DOMESTIC MILITARY INSTALLATIONS

The United States is the world's largest oil consumer. With consumption exceeding 20.5 million barrels of oil per day (bbl/d), the equivalent of 861 million gallons, the United States consumes nearly three times as much oil as China, the second largest oil consumer. Domestic production of oil accounts for 8.3 million bbl/d, requiring

12.2 million bbl/d of imported foreign oil (Top World Tables, 2006). Reliance on foreign oil for 60 percent of domestic demand requires strong trade partners willing to provide oil to the United States. The use of large amounts of fuel for energy production has both financial costs and emission control policy requirements. The following sections describe these costs and emission policies.

1. Financial Cost

The federal government uses massive quantities of energy to power its operations, although it accounts for less than 2 percent of total U.S. energy usage. The Department of Defense (DoD) is the biggest single consumer of this energy. DoD's 500,000 buildings and facilities consume 75 percent of the energy used by the federal government and 1 percent of the nation's energy. The fuel costs fall into two categories: direct and contingent, as clarified below.

a. Cost of Energy Consumption

In fiscal year (FY) 2005, DoD spent $10.9 billion for 919 trillion site-delivered British Thermal Units (BTU's) of energy for use by military installations. Based on the 2005 Defense Authorization Bill, this amount represented 15.6 percent of DoD's operations and maintenance budget exclusive of supplemental appropriations (National Defense Authorization Act for Fiscal Year 2005, 2004).

b. Cost of Noncompliance with Environmental Laws and Agreements

A DoD facility may be subject to fines and penalties if it is found to be in noncompliance with federal, state, or local environmental laws and regulations. This can result in fines and penalties that may have a negative impact on DoD's mission by limiting its ability to test new equipment and train personnel or by preventing its use of noncompliant facilities and equipment. (ODUSD (I&E), 2006)

DoD manages environmental compliance activities to ensure full and sustained compliance with U.S. environmental laws and overseas environmental obligations. These activities maintain robust self-audit and corrective action programs;

and identify and correct noncompliance in a timely manner (ODUSD (I&E), 2006). Despite its best efforts, occasional instances of noncompliance arise and, as a result, DoD is subject to enforcement actions and the associated fines and penalties. DoD makes a concerted effort to reduce enforcement actions because they negatively impact on human health, the environment, and the mission by diverting resources away from other activities.

Figure 1 shows the trends in fines and penalties assessed from FY2002 through FY2006. Since FY2002, the amount DoD has been assessed for noncompliance has decreased 49 percent. The amount of fines assessed during FY2006 totaled nearly $1.2 million, approximately $300,000 less than FY2005. While the dollar amounts of noncompliance fees are insignificant compared to the billions of dollars in total energy expenditures, such fees represent nonvalue added costs of energy consumption.

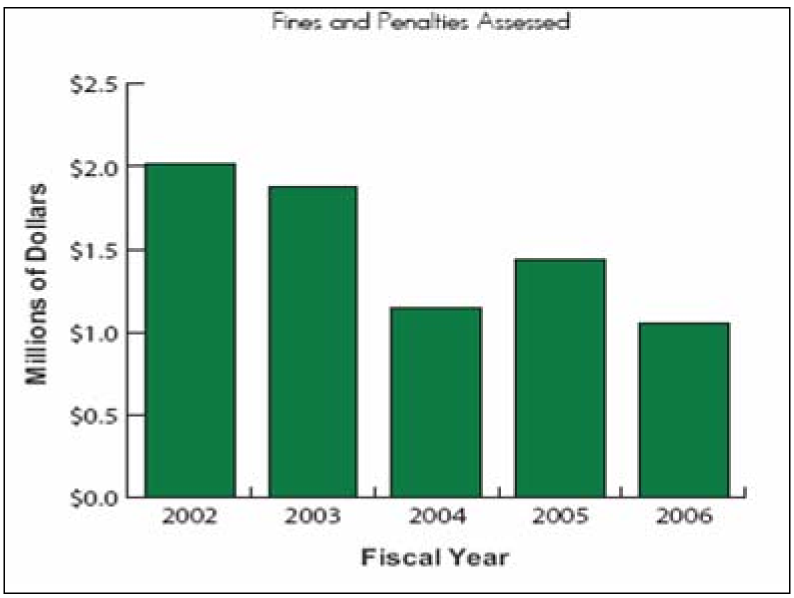

Figure 1. DoD Fee Cost of Environmental Noncompliance [From ODUSD (I&E), 2006]

Energy consumption has both financial and environmental costs. In an effort to reduce the energy consumed by the government, several laws requiring reductions in government installation energy intensity and emissions, within a time line of several years, have been established.

2. Clean Air Act (CAA) Requirements

Air pollutants that are generated from normal DoD operations can cause injury to human health, harm the environment, and cause property damage. The CAA regulates emissions of these air pollutants from area, stationary, and mobile sources. DoD Instruction DoDI 4715.6, "Environmental Compliance," establishes a framework for measuring DoD's compliance with the CAA.

DoD's Compliance Program helps the Department manage air pollutant emissions and make appropriate investments to promote the attainment of National Ambient Air Quality Standards (NAAQS), while leveraging energy conservation opportunities. DoD tracks emissions for both criteria air pollutants and total hazardous air pollutants (HAPs). Criteria air pollutants are the six principal pollutants that have NAAQS:

- ozone (O_3)
- nitrogen oxides (NOX)
- inhalable coarse and fine particulate matter (PM_{10} and $PM_{2.5}$, respectively)
- sulfur dioxide (SO_2)
- carbon monoxide (CO)
- lead (Pb)

DoD reports volatile organic compounds (VOCs) with the criteria pollutants because VOCs and NOX are precursors to O_3, which is not directly reported. Congress identified nearly 200 HAPs known to have harmful health effects under the CAA. Most of the HAPs are organic compounds, such as benzene, although some are toxic metals and their compounds. Table 3 details DoD's CAA emissions in Calendar Year (CY) 2005.

CY2005 CAA Air Emissions

	DoD Totals (tons/year)
Total HAPs	2,428.52
Criteria Air Pollutants	
VOCs	9,583.88
NO_x	17,673.78
PM_{10}	44,614.54
$PM_{2.5}$	280.61
SO_2	18,028.08
CO	56,884.13
Pb	21.92

Table 3. DoD Emission Total [From ODUSD (I&E), 2006]

DoD reports annually on metrics designed to ensure its activities remain protective of air resources. To minimize the impact on air resources, DoD collects information on the quantity of regulated air pollutant emissions identified in the laws and regulations of the United States or host nation. These are known as Final Governing Standards and they reduce energy use and manage the cost of air pollution (ODUSD (I&E), 2006).

C. ENERGY USAGE AND COST BY MILITARY FORWARD OPERATING BASES

The need for fuel supplies is not a new requirement. Thousands of years ago, Sun Tzu (1983) wrote in The Art of War about the need for fighting units to maintain supply lines—"An Army without its baggage train is lost; without provisions it is lost; without bases of supply it is lost."

The fuel needs of deployed troops are analogous to the needs of the country. Additionally, an overseas presence requires lengthy logistical supply lines to meet the needs of deployed troops. These supply lines have increasingly become a target for guerilla-style asymmetric warfare against U.S. forces. Military operations highlight both the requirement for and vulnerability of military fuel convoys.

One of the most well-known examples of a military energy crisis occurred near the end of World War II. As U.S. General George Patton raced through France, he quickly outran his supply lines and the ability to refuel his trucks and tanks. On August 28, 1944, Patton declared, “At the present time our chief difficulty is not the Germans, but gasoline. If they would give me enough gas, I could go all the way to Berlin!” Three days later, despite the efforts of the famed Red Ball Express fuel convoy trucks, Patton and his men were stranded dry. The chance to sweep through France into Germany soon passed (Tally, 2001).

Current military operations are also heavily reliant on petroleum-derived fuels. According to the Defense Energy Support Center (DESC), during April 2006, the U.S. military brought a total of 1.29 million gallons of fuel per day into Iraq. From Kuwait alone, U.S. troops brought 890,000 gallons of fuel per day across Iraq’s southern border.

On July 25, 2006, the Commanding General of Multi-National Force-West in Iraq (CG, MNF-W) issued a Joint Staff Rapid Validation and Resourcing Request for renewable energy systems. This request highlighted the operational need for a renewable and self-sustainable energy solution capable of reducing the number of fuel convoys, while meeting the electricity requirements of forward operating bases. The purpose for this request was to decrease the frequency of logistics convoys on the road, thereby reducing the danger to U.S. forces. One proposal to meet this requirement is the process of generating electricity through conversion of field waste. The amount by which efforts to meet this proposal can reduce risk and provide possible financial incentives is one focus of this research (Commanding General, Multi-National Force-West, 2006).

1. Financial Cost

a. Fuel Cost at Depot

DoD currently prices fuel based on the wholesale refinery price, <u>not including the cost of delivery to its customers</u>. This “refinery pricing assumption” excludes four key cost-generators:

- The true picture of end-to-end fuel utilization is lost to decision making
- Refinery-pricing does not reflect DoD's true fuel costs
- Refinery-pricing actually masks the benefits of energy efficiency
- Under-pricing by design also distorts platform design choices

The DESC acts as the market consolidator and wholesale agent for DoD. For simplicity in dealing with its service customers, the Office of the Secretary of Defense (OSD) establishes a "standard fuel price" annually. The standard price does not reflect the cost to the military services of delivering the fuel from the DESC supply point to the ultimate consumer, such as via tanker, ship, or aircraft. The cost of delivery is absorbed by each military service budget and is spread across many accounts, meaning that the actual cost of delivering fuel is not captured by accounting systems and not factored into important investment decisions.

Figure 2 shows the wholesale elements of fuel supply covered by the DESC price:

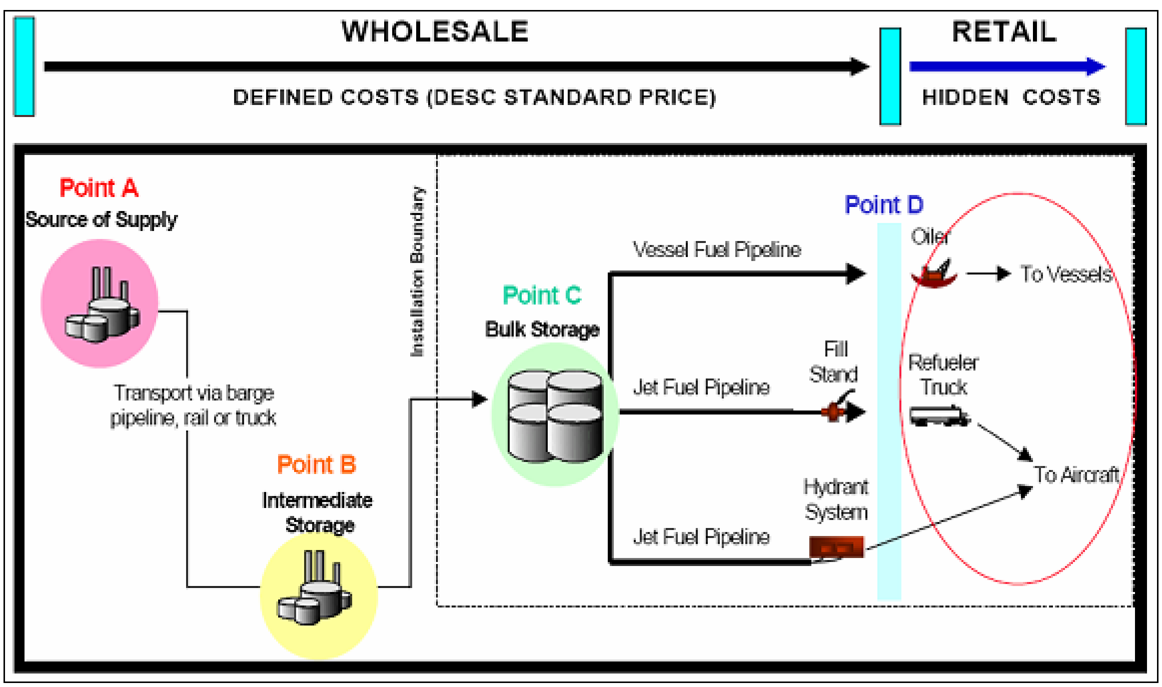

Figure 2. DoD Bulk Fuel Supply Chain [From Cooper, 2007]

b. *Fully Burdened Cost of Fuel*

The difference between the wholesale price and true cost reflects what the services must pay to handle, store, and deliver the fuel. In FY1999, the standard DESC fuel mix price (average price of the fuel sold) was $0.87 per gallon, and by FY2007 it had increased to $2.14. Fuel inflation over this period far exceeded Operations and Maintenance (O&M) inflation indices over the same time period. If the fuel inflation rates had matched O&M inflation rates, an $0.87 per gallon fuel price in 1999 would have risen to only $1.14 in 2007.

The true cost of this fuel is much higher, with estimates ranging up to hundreds of dollars per gallon for Army forces deep into the battlespace. Since these costs are not used in economic analyses, it is likely that a suboptimal allocation of resources has been the result (DESC, 2007; USD (AT&L), 2001).

A consequence of using the DESC price is that the logistical cost of delivering fuel to platforms is considered free. However, it is possible that about a third of DoD's budget, half of its personnel, and around 70 percent of the tonnage delivered by the logistics effort is fuel. The result is that the Services maintain infrastructures to ensure fuel delivery, including large and small surface trucking organizations, naval fleet tankers, aerial refueling aircraft, and maintenance and logistics organizations, all of which contribute to significant overhead costs. Increases in fuel efficiency would correspondingly shrink this overhead burden, enabling savings through reductions in logistics requirements (USD (AT&L), Improving Fuel Efficiency of Weapons Platforms, 2001).

Without the full costs of fuel delivery and supporting infrastructure being known, understood, and factored into the cost of the fuel, the true benefits of improving platform efficiency are not fully considered in acquisition requirements and processes. This could create incentives to introduce fuel efficiency into those processes, thereby cutting battlefield fuel demand and reducing the fuel logistics structure needed to deploy and employ weapons systems. Until policy guidance requires emphasis on weapons system fuel efficiency and the true cost of provisioning fuel to end users is gathered and

understood, there is no financial incentive for leaders, managers, or operators to depart from current practices (USD (AT&L), Improving Fuel Efficiency of Weapons Platforms, 2001).

2. Additional Burden Cost of Supplies

One cost of transporting battlefield supplies, including fuel, is beyond dollar amounts. Many forward operating areas require supply convoys to pass through hostile territory en route to their destination. This resupply need became a liability when insurgents began targeting convoys coming from Kuwait, Jordan, and Turkey. The result was an increase in improvised explosive device (IED) attacks against these convoys. At times, as many as 30 IED attacks per week occurred (Wagner, 2007). Any convoy transporting supplies in hostile territory risks being attacked. Those providing security must protect the convoy or risk stranding others dependent on those supplies. This security vulnerability is a significant qualitative factor in the overall cost of fuel and other supplies, but is not included in the financial calculations.

3. The Case for Battlefield Energy Efficiency

U.S. commanders in Iraq have asked the Pentagon for portable renewable energy sources (CG, MNF-W, 2006) to cut back on the number of ground convoys that transport fuel into Iraq The director of the Rapid Equipping Force (REF), Army Colonel Greg Tubbs, is working with a group of energy experts to find commercial products that satisfy two major requirements: they must be deployable within 18 months and reduce fuel consumption by 40 percent (Wagner, 2007).

Dan Nolan (COL, USA (Ret.)), head of REF task force’s energy efforts, stresses the importance of decreasing the fuel need without diminishing mission capability. The need to find small, transportable devices is established by focusing on solutions for forward operating bases, where the U.S. military does not plan on having a permanent presence (Wagner, 2007).

Energy production and savings projects taking several approaches are currently under development. Three areas of promise include: solar/wind power, field waste-to-

energy conversion, and packaging material-to-energy conversion. These technologies rely on either the nontraditional use of resources that are available in the intended operating areas or on the reuse of discarded materials. One program being considered focuses on the development of a device that utilizes field waste-to-energy conversion to reduce the external fuel requirement of forward operating bases. Benefits beyond direct fuel cost savings include the reduced need for fuel convoys and significant reductions in waste disposal costs.

D. WASTE AT FORWARD OPERATING BASES (LMI, 2004)

Waste generated during deployments typically falls into four categories:

- general solid waste (e.g., paper, wood, plastic, human, and food waste)
- hazardous waste
- used petroleum products
- medical waste

During an operation, individual units are responsible for disposing of their waste until centralized waste disposal operations are in place. The centralized operations often become available when semipermanent or permanent base camps are established.

Waste disposal practices vary by location. In some countries, the Army has taken advantage of a developed waste disposal infrastructure after establishing base camps. In Kuwait, for example, much of the Army's waste is disposed of through local facilities.

In semideveloped areas such as Afghanistan, the Army tends to make more use of contractors, either deployed or local. Deployed contractors use the local waste disposal infrastructure wherever possible, or otherwise transport the waste to where more developed facilities exist. Additionally, Army units in such circumstances often burn or bury a good deal of waste. Unfortunately, such disposal sometimes includes hazardous materials, which are supposed to be handled separately. Used oil often is sold to local nationals, who use it as fuel.

The burning or burying of waste is common in host countries with little or no waste disposal infrastructure. Depending on its content, the burning or burying of waste

can have adverse local environmental effects and be an irritant to local residents. In undeveloped or deployed areas, local unit commanders usually decide how waste is to be handled. Burning and burying are typical, though local nationals may collect some of the solid waste and recycle a portion of it.

The primary motivation for Army waste disposal is to avoid health threats to the troops. To unit commanders, the most important thing is to rid themselves of the waste, not necessarily to dispose of it in the most environmentally benign way. For this reason, environmental concerns sometimes are addressed only if they coincide with health concerns. For example, some units will mix hazardous or medical waste with general waste, or bury used lubricants rather than dispose of them in accordance with American domestic standards. These practices are most common when units are moving rapidly and have little accountability (LMI, 2004).

A 2004 study by the Logistics Management Institute (LMI) analyzed the value of waste in the field. In characterizing military waste, data was gathered at Fort Irwin, California, where military units conduct field training operations. The waste streams of Fort Irwin were found to be analogous to those of actual field-deployed units. With regard to waste generation, Figure 3 shows that LMI found:

- approximately 79 percent of the waste is potentially convertible into fuel;
- much of the waste is made up of wood, cardboard, plastic, and food; and
- a deployed soldier generates an average of 7.2 pounds of convertible solid waste per day (LMI, 2004).

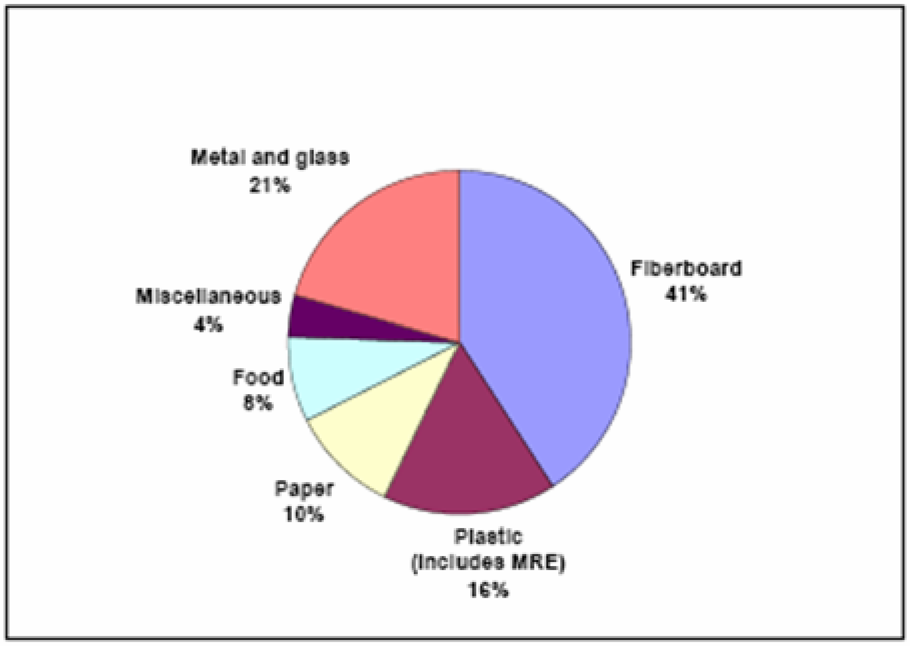

Figure 3. Field Waste Content [From LMI, 2004]

E. RESEARCH OUTLINE

This research examines the return on investment of possibilities for complying with mandates to increase energy efficiency at domestic and deployed installations. Chapter II provides background on mandates to increase energy efficiency and methods used to assess potential energy cost savings. Chapter III discusses ways to create energy savings as well as possible qualitative and quantitative metrics for measuring energy cost reductions. Chapter IV describes the methodology used in this research for determining cost reductions and returns. Chapter V provides data from previous studies and computes comparative life-cycle cost estimates for traditional and proposed energy projects. These estimates are used to assess the return on investment of energy efficiency projects. Chapters VI and VII present research observations, findings, and conclusions. Each chapter is bifurcated into domestic and deployed installation elements as illustrated in Figure 4.

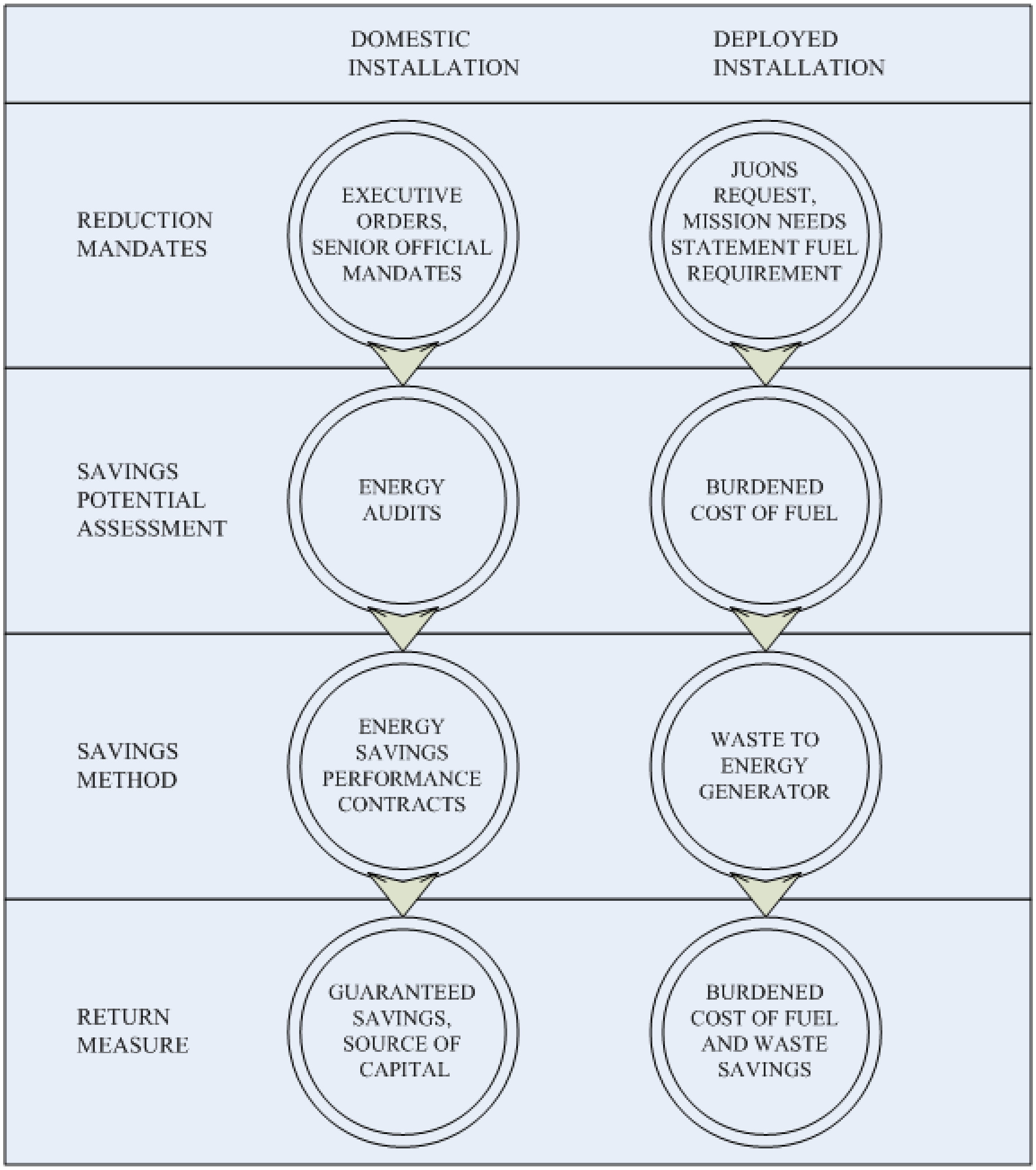

Figure 4. Research Roadmap

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II. PROBLEM AND BACKGROUND

A. DOMESTIC INSTALLATIONS: DETERMINING RETURN ON ENERGY EFFICIENCY INVESTMENTS

1. Policy Directives and Financial Incentives

Most annual energy expenditures are paid for via accounts designated for Operations and Support (O&S). In each Service, these O&S accounts pay for energy utilities as well as civilian salaries, training, maintenance, fuel, supplies, and repair parts. O&S expenditures are annual funds that can only be spent for the needs of the year for which they are appropriated. Most energy efficiency projects do not have a one year payback and therefore, any investment with O&S funds would force a reduction in other aspects of O&S spending for that year. Commanding officers have little incentive to invest now in a project that will not pay dividends until years after their tour of duty is completed. Additionally, O&S funds are not intended as investment or military construction (MILCON) funds. Financial savings from energy efficiency projects benefit O&S accounts, while the funding required to implement those projects usually comes from investment or MILCON funds. This timing, cost, and benefit structure provides little incentive to invest in energy saving projects.

Recent guidance from senior government officials offers ways to address these concerns and provides options for financing energy efficiency projects. Several ongoing efforts seek to increase the energy efficiency of military installations and to reduce the financial and environmental costs of energy consumption. One important element of these efforts is the energy audit.

a. Energy Audits

This section discusses the role that energy audits play in determining the most effective use of investment dollars for installation energy efficiency projects. The term “energy audit” is defined below, followed by a discussion of military facility energy audit requirements. The three major types of energy audits are described, with an explanation of energy conservation versus efficiency and methods for determining project

cost effectiveness. An overview of Executive Order 13423 illustrates mandated energy reduction requirements. Finally, conclusions regarding the continued use of energy audits at government installations are presented.

One of the first steps in determining the potential for economically viable energy reduction is conducting an energy audit. An energy audit seeks to identify all of the energy streams into a facility and to quantify energy use according to its discrete functions. An energy audit is analogous to the monthly closing statement of an accounting system. One series of entries consists of amounts of energy that were consumed during the month in the form of electricity, gas, fuel, oil, steam. The second series lists how the energy was used for lighting, air conditioning, heating, etc. The energy audit process must be carried out accurately enough to identify and qualify the energy and cost savings that are likely to be realized via investment in an energy savings measure (Thumann, 2003).

Energy audits evaluate current energy usage and assist installations in determining the best locations to incorporate energy savings measures. The Energy Policy Act of 2005 (EPAct 2005) requires federal agencies to audit approximately 10 percent of their facilities each year. Since doing so may be cost prohibitive, DoD components are encouraged to use either appropriated funding or alternative financing through ESPC projects to conduct their energy audits (EPAct, 2005).

*The "Scoping" Audit***.** This cursory examination of a facility and its energy-using systems is often not much more than a walk-through to determine whether the potential exists for an economically viable project. This preliminary work determines whether a much more expensive "engineering feasibility" study is warranted. The scoping audit includes a basic description of the facility, its function, information on energy-using systems, and gross energy use. During a scoping audit, a simple descriptive inventory of energy-using systems and equipment is assembled along with nameplate data, age, and notes on condition. Utility and other energy bills are reviewed and, where appropriate, energy indices are calculated. Quick calculations are made that suggest possible energy savings. These preliminary calculations are designed primarily to provide enough information to determine whether a detailed engineering audit is justified. The

scoping audit costs money, but it is “cheap insurance” when compared to the cost of an engineering feasibility study that was not warranted. If an energy scoping audit suggests that an opportunity for a viable project exists, and the government agency agrees, then a detailed engineering feasibility study is conducted (Hansen, 2003).

The Engineering Feasibility Study. This study builds on the preliminary data provided in the scoping audit, but substitutes measurements for estimates and verification for approximation. It examines facility use and patterns to determine function, occupant loads, timing, and all of the other factors that influence energy usage. The building shell is evaluated to determine points of energy loss or opportunities for improvements. Lighting is examined with particular care. The auditor will rarely take the word of building occupants or facility managers as to run time; thus, actual measurements are almost always justified. Heating, cooling, and other equipment is evaluated and required temperature, humidity, air exchange rates, and other environmental parameters are carefully noted. All energy-using equipment is inventoried and its condition noted, along with hours of operation and energy required. This type of audit is often referred to as a “traditional” energy audit.

At least 12 months’ worth of utility bills are examined, with attention to demand charges and load profiles. Rate schedules are checked to ensure the correct rates are being charged. Impressive “energy savings” are often the result of applying the correct rate schedules. In some instances, a review of rate schedules finds that facilities have previously been undercharged for utilities and now are liable for the cumulative difference of hundreds of thousands to millions of dollars (IG DoD, 2002). Weather statistics for similar time periods may be important if variations from normal weather patterns have been sufficient to have a significant bearing on energy use and the measures under consideration are temperature dependent.

Equipment maintenance and the skill level of personnel performing maintenance impact energy consumption. This information provides a basis for determining what equipment should be replaced and gives an indication of the amount of

training needed to run it. The objective of this training is to assure that any new equipment will operate near design and projected energy savings will be achieved throughout the life of the project.

Equipment additions, replacements, modifications, or improvements are recommended based on calculated payback periods, and are selected with the expectation that certain energy efficient improvements will be achieved (Hansen, 2003).

Investment Grade Audit (IGA). Based on the premise that energy efficiency is an investment and not an expense, an IGA should offer an investor a reliable guide to the investment potential of recommended efficiency measures. In addition to the scoping audit and engineering feasibility study, the IGA considers additional economic and financial factors.

A detailed examination of the ownership and financial solvency of the facility owners has been incorporated into the technical feasibility study. Many lending institutions require a checklist of financial health to be completed by the facility owners prior to considering a financial package for an energy efficiency project. The cost of money—even its availability—depends on the risks associated with a given project. A strong IGA that has clearly addressed potential risks is reassuring to financiers. A major function of an IGA, therefore, is to present the identified risks, document the possible management mitigating strategies, and assess the total impact on the project. Creating a "bankable" project depends heavily on the information provided in an IGA. While more costly than a traditional audit, these additional IGA costs can easily be offset by lower interest rates as well as the ease of obtaining financing (Hansen, 2003).

Energy conservation and energy efficiency are often used interchangeably despite having unique meanings. Energy conservation means using less energy. Energy efficiency means using what must be used as efficiently as possible. In manufacturing, an old machine that uses 10 units of energy to produce 100 widgets may be replaced by a new machine that uses 15 units of power, but produces 200 widgets. While more energy is required for the machine, less energy is required per widget. That is efficiency, but not conservation. A machine that produces 80 widgets with 9 units of energy demonstrates

conservation, but not efficiency. A machine that produces the original 100 widgets with 9 units of energy would demonstrate both conservation and efficiency, while a machine that produces 90 widgets with 10 units of energy exhibits neither conservation nor efficiency. Efficiency measures will tend to increase the overall cost effectiveness better than conservation efforts alone.

b. Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management

Signed by President Bush on January 24, 2007, Executive Order 13423 (EO 13423) increases several efficiency and conservation goals previously set in earlier Executive Orders and the Energy Policy Act of 2005 (Clinton, 1999). Among other requirements, EO 13423 sets forth federal agency goals of improving energy efficiency and reducing greenhouse gas emissions, through reduction of energy intensity by 3 percent per year or 30 percent in sum through FY2015, relative to FY2003 energy use baselines. EO 13423 also directs the implementation of renewable energy generation projects on agency property for agency use (Bush, 2007).

It is important to note that EO 13423 does not set goals in terms of cost reductions. While cost reductions should follow use reductions, the volatility of energy prices causes a moving cost target that is beyond the control of government departments. Reductions in use are both measurable and controllable by the departments, making them ideal qualities to be subjected to an audit.

Energy intensity is predominately measured in terms of British Thermal Units per gross square footage (BTU/gsf). Because this unit takes into account changes in the overall size of the agency installation square footage, it is more a measure of efficiency than conservation.

To meet the requirements of EO 13423, agencies must conduct energy audits to identify projects that have strong potential for energy savings as a result of initial investments in energy efficient projects. Once projects with strong savings potential are identified, the agency must determine the best way to pay for them.

c. Energy Savings Performance Contracts (ESPCs)

On August 3, 2007, James L. Connaughton, Chairman of the Council on Environmental Quality, Executive Office of the President, issued a memorandum to the heads of executive branch departments and agencies directing the increased use of ESPC programs. These contracting programs utilize private investment capital to finance energy efficient programs at government installations. The savings from reduced energy usage are then used to pay off the capital investment and investor "debt service." This memorandum estimates that in order to meet EO 13423 goals, agencies must invest 20 percent of their annual energy costs in efficiency enhancements, half of which must be in the form of ESPCs. Since 1985, federal agencies have invested almost $7 billion in energy efficientcy improvements, half of which has come from ESPCs. Cumulative savings as a result of these projects is estimated to be as high as $8.5 billion (Connaughton, 2007; Kaufmann, 2007).

ESPCs with federal agencies are subject to review by the Government Accountability Office (GAO) and other auditing entities in the federal government. The audit opinions that ESPCs have received in the past are mixed.

In 2001, The Army Audit Agency's Consulting Report No. AA01-718 "Audit of Energy Savings Performance Contracts" concluded that compact fluorescent light bulbs could save approximately $16.2 million and 640 million kilowatt hours compared to existing incandescent light bulbs over the life-cycle of the investment. These projected energy and monetary savings were agreed to by the Principal Deputy Assistant Secretary of the Army (Installations and Environment) and the Office of the Assistant Chief of Staff for Installation Management, Facilities and Housing (Army Audit Agency, 2001).

Not all ESPCs are so universally accepted by both federal agencies and contractors. In 2000, an Army Audit Report determined that baseline energy statistics were inaccurate primarily because of malfunctioning electrical and gas meters and incorrect meter readings. The report concluded that Fort Polk, Louisiana overpaid the contractor at least $1,238,000 from January 1994 through June 2000 for energy savings.

The report recommended that the Commander, Joint Readiness Training Center, and Fort Polk recoup the overstated payments (Army, 2000). Whether intentional or accidental, the inaccuracies stress the specific importance of energy audits in providing additional oversight to energy-related government contracts.

ESPCs, like all government contracts, allocate risk between the service provider and the United States government. ESPC is a means of using utility savings to pay for all project costs and is considered the most cost-effective means of completing building energy upgrades that were not funded via direct appropriations. There are many types of investment projects, such as energy-management systems, interior and exterior lighting, boiler replacement or repair of steam systems, and replacement of Heating, Ventilation, and Air Conditioning (HVAC). This form of contracting normally guarantees project investment costs, utility savings, and performance of installed equipment, with the majority of risk borne by the contractor, not the government.

The Department of Energy explains: An ESPC project is a partnership between the customer and an energy service company (ESCO) (DOE, 2006, June). The ESCO conducts a comprehensive energy audit and identifies improvements that will save energy at the facility. In consultation with the agency customer, the ESCO designs and constructs a project that meets the agency’s needs and arranges financing to pay for it. The ESCO guarantees sufficient savings to at least pay for the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency. Contract terms up to 25 years are allowed (DOE, 2006, June). Figure 5 illustrates the allocation of energy and energy-related expenses before, during, and after an ESPC.

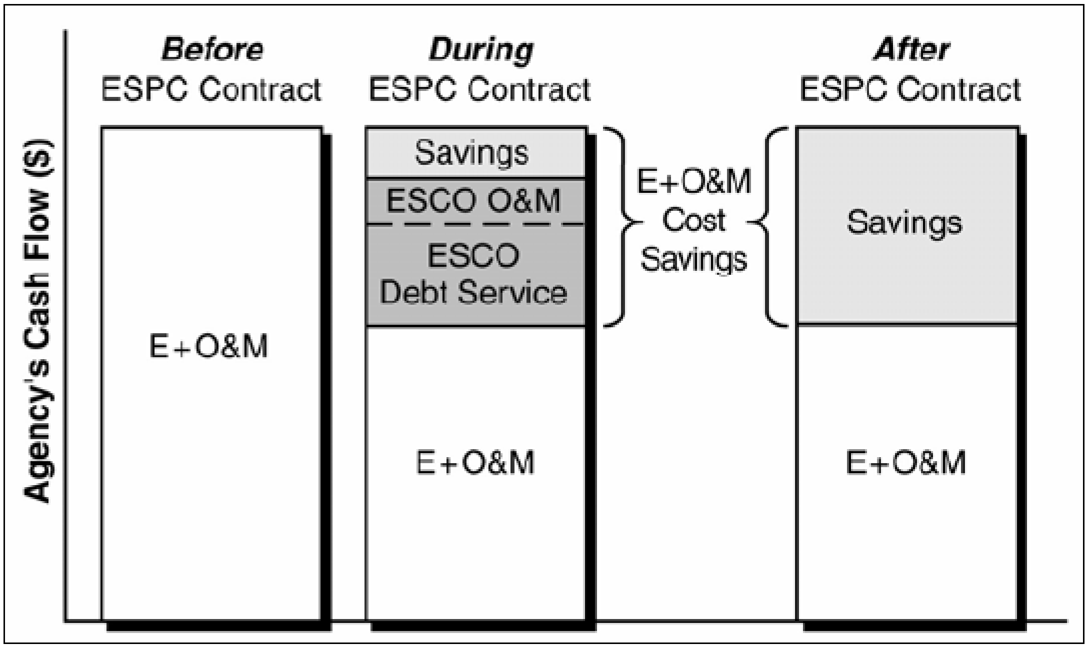

Figure 5. Reallocation of Agency Payments for Energy and Energy-Related O&M Expenses [From DOE, 2007]

Since 2005, more than 400 federal ESPC projects, in 46 states, by 19 federal agencies have generated $5.2 billion in energy cost savings. The use of ESPCs is ideal for organizations that seek out alternative means of funding programs. As the discretionary portions of the DoD budget continue to become strained, high competition for those funds may leave critical programs dry (DOE, 2006, June).

Many facilities throughout DoD were built shortly after World War II and have not been replaced. Dated DoD equipment and assets—such as the B-52 bomber, SH-60 helicopter, and many others—are continuously being funneled additional funds. This funding is higher than normal funding would be for these assets due to increased maintenance, poor fuel economy, dated insulation techniques, and lack of funding to support replacements. Thus, DoD continues to live with existing problems. The ESPC is a means to cut costs, while continuing overall functionality of facilities and assets.

2. Carbon Emission Reductions

Federal mandates prior to EO 13423 required reductions in energy intensity for military installations. From 1985 to 2005, Navy and Marine Corps installations reduced

energy intensity by approximately 30 percent. Figure 6 illustrates energy intensity reductions during this period for the Department of the Navy (DON).

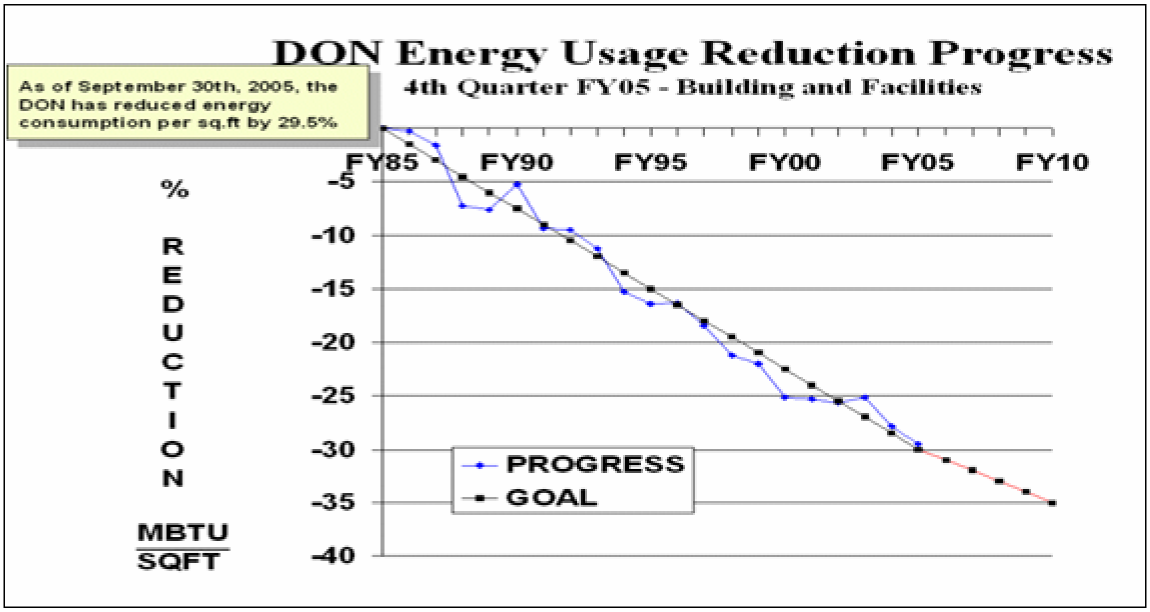

Figure 6. Department of the Navy Energy Usage Reduction Progress Since 1985 [From energy.navy.mil, 2005]

Few energy-consuming activities directly provide their own energy supply on site. Most installations, whether civilian or military, receive power from power plants that must convert chemical energy to mechanical energy to turn generators, which, in turn, produce electrical energy. This electricity must be transmitted across several miles and voltage step down transformers, followed by additional engineering losses, before being applied to its final purpose (e.g., powering an air conditioning unit). However, powering the air conditioner is not the end state; maintaining a comfortable temperature is the desired outcome. The conditioned air must be delivered to the required area suffering heat gain along the way. Such process losses are similar to the theoretical system illustrated in Figure 7. Provided the input to output ratio remains constant at 10 to 1, a 10 percent reduction in energy demand could prevent the processing of 10.5 units of energy input. While installation specific numbers may differ, this reduction in demand energy intensity illustrates energy supply chain emissions savings in excess of direct usage differences.

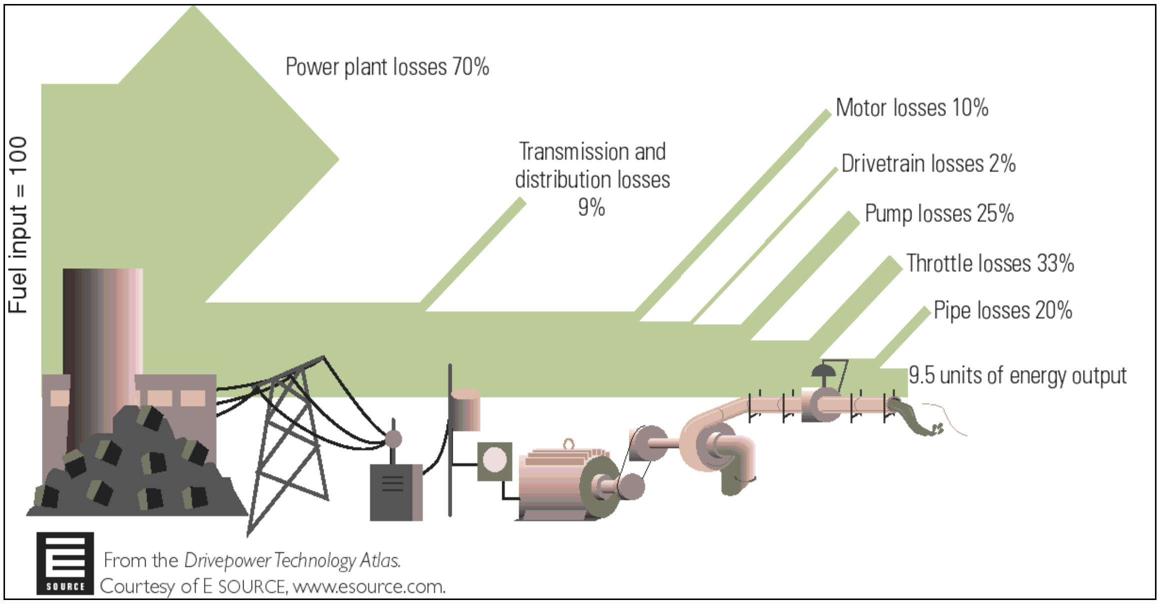

Figure 7. Energy Supply Losses [From Lotspeich, 2003]

B. DETERMINING RETURN OF ENERGY EFFICIENT INVESTMENTS AT MILITARY FORWARD OPERATING BASES

This section addresses the need for managing waste at a military forward operating base. Then, the general issue of converting waste to energy is outlined, followed by an emerging technology to accomplish this waste-to-energy task at a forward operating base.

1. Need for Managing Waste at a Military Forward Operating Base

Managing waste at military forward operating bases can impact unit security, logistics, and financial cost. Sections I.D. and III.C.1.e.-g. of this research further addresses the impact of waste management at forward operating bases.

2. Waste-to-Energy Conversion Process

All organic waste contains energy. Oil, coal, wood, and garbage all contain heat energy that is released when burned. The amount of heat energy in each substance determines how much energy is released. Heat amounts for diesel fuel and coal are higher than for wood and solid waste. One gallon of diesel fuel contains about the same energy

as 28 pounds of municipal waste. The amount of energy in one ton of solid waste (9.945 Million BTU/short ton) is approximately the same as in one ton of wood (9.961 Million BTU/short ton) (EIA, 2005).

Extracting energy from organic sources is certainly not a new idea. Humans have been burning organic materials in the form of wood, oil, and trash for thousands of years. Coal, the combustible sedimentary rock created from organic plants that lived millions of years ago, provided the fuel for the Industrial Revolution and is still the most widely used fuel for production of electricity in the United States and worldwide. In 2005, more than half (51 percent) of the country's 3.9 trillion kilowatt-hours of electricity used coal as its source of energy (EIA-Annual Energy Review, 2006).

Waste-to-energy plants generate enough electricity to supply almost three million households (1 percent of the U.S. total). However, providing electricity is not the major advantage of waste-to-energy plants. In fact, it costs more to generate electricity at a waste-to-energy plant than it does at a coal, nuclear, or hydropower plant. The major advantage of burning waste in a large-scale domestic incinerator is that it reduces the amount of garbage buried in landfills (National Energy Education Development Project, 2006).

The average American creates more than two cubic yards of waste per year. The residual ash from combustion of this waste occupies one-eighth the unburned volume. For every one landfill of ash, seven landfills of unburned waste are not required (National Energy Education Development Project, 2006).

Harnessing the energy of organic materials for the production of electricity usually requires factory-sized incinerators in fixed, permanent buildings or burning refined fossil fuels in portable generators. Establishing permanent infrastructure is neither compatible with the mission of military operations nor economically feasible with the relatively short duration of most military operations. Traditional portable generators require the availability of specific petroleum products such as gasoline or diesel fuel, which must be transported and stored according to strict conditions.

3. Prototype Development of a Tactical Garbage-to-Energy Generator

For the past three years, research and development has been conducted on a tactical garbage-to-energy refinery (TGER). During development of this project, the REF worked with Purdue University, Defense Life Sciences LLC (DLSci), the Defense Advanced Research Projects Agency (DARPA), and other defense organizations to produce a working prototype (Wagner, 2007). Significant acquisition milestones achieved are:

August 13, 2004 – Army Contract Award: DLSci is awarded a contract for Army Phase I Small Business Technology Transfer (STTR) "Tactical Bio-refinery for Forward Fuel Production." DLSci and its partners conduct feasibility analysis and prepare for phase II prototyping of a tactical garbage-to-energy refinery.

December 15, 2004 – Army Contract Award: DLSci is awarded a Phase I Small Business Innovation Research (SBIR) for "Tactical Bio-refinery" with U.S. Army Tank-automotive and Armaments Command (TACOM). Research and development (R&D) in this contract will be complementary to its current efforts with the Army STTR "Tactical Bio-refineries for Forward Fuel Production."

September 29, 2005 – Phase II STTR Contract Award: DLSci awarded STTR Phase II contract for prototype development of "Tactical Bio-refinery for Forward Fuel Production." DLSci and its team-members will complete their prototype effort within 15 months and conduct testing and evaluation at Edgewood Chemical Biological Center (ECBC).

November 2006 – Successful test of first prototype TGER performed.

December 31, 2006 – TGER Prototype Delivered: DLSci delivers the first prototype Tactical garbage-to-energy refinery to the Army (www.dlsci.com/news_include.html, 2007).

April 2007 – Project Initiation of TGER prototype # 2.

A schedule of near-term developments and milestones includes:

Expected Delivery of both TGERs	December 2007
Testing at ECBC	January-March 15, 2008
Safety Confirmation/Release	March 2008
System in Theater	July 15, 2008
Assessment	December 15, 2008

a. Project Cost

Compared to major acquisition programs, the TGER program is relatively inexpensive. The costs and impacts of the TGER program are dependent on current and future efforts to reduce the physical size of each TGER and the results of system field tests. Current estimates of developing, upgrading, testing, and evaluating two TGER units are:

Development of the TGER	
Option A: TGER #2	$1.3M
Option B: TGER #2 plus upgrade TGER #1	$0.2M (net $1.5M)
ECBC Program/Engineering Support	$0.3M
Assessment Support (6 months)	$0.4M
Total	$2.2M

Option B considers development of TGER #1 as a sunk cost and shows only a marginal cost of upgrading to TGER #2 standards. Learning curve considerations have reduced the total cost of each current standard TGER from $1.5 million to $1.3 million. Future learning curve savings are as yet undetermined (Nolan, 2007).

b. Project Performance

The tactical garbage-to-energy refinery is actually three technologies in one: a bioreactor that uses enzymes and microorganisms to turn food waste into ethanol; a gasification unit that turns plastics, paper, and other residual waste into methane and low-grade propane; and a modified diesel engine that can burn gas, ethanol, and diesel fuel in variable proportions (Hamilton, 2007). The TGER operation is summarized in the following four steps:

1. The shredder rips up waste and soaks it in water.
2. The sludge is pumped into the bioreactor, and enzymes break it down into carbohydrates and then into simple sugars, which yeast metabolizes into ethanol.
3. The pelletizer compresses undigested waste pellets and feeds them into a gasification reactor that burns them in a low-oxygen, high-temperature environment to produce a composite gas.
4. The ethanol is combined with the composite gas and injected into a diesel generator, where it's mixed with two percent diesel fuel to generate electricity (Behar, 2007).

Figure 8 is a diagram of the major parts of the TGER.

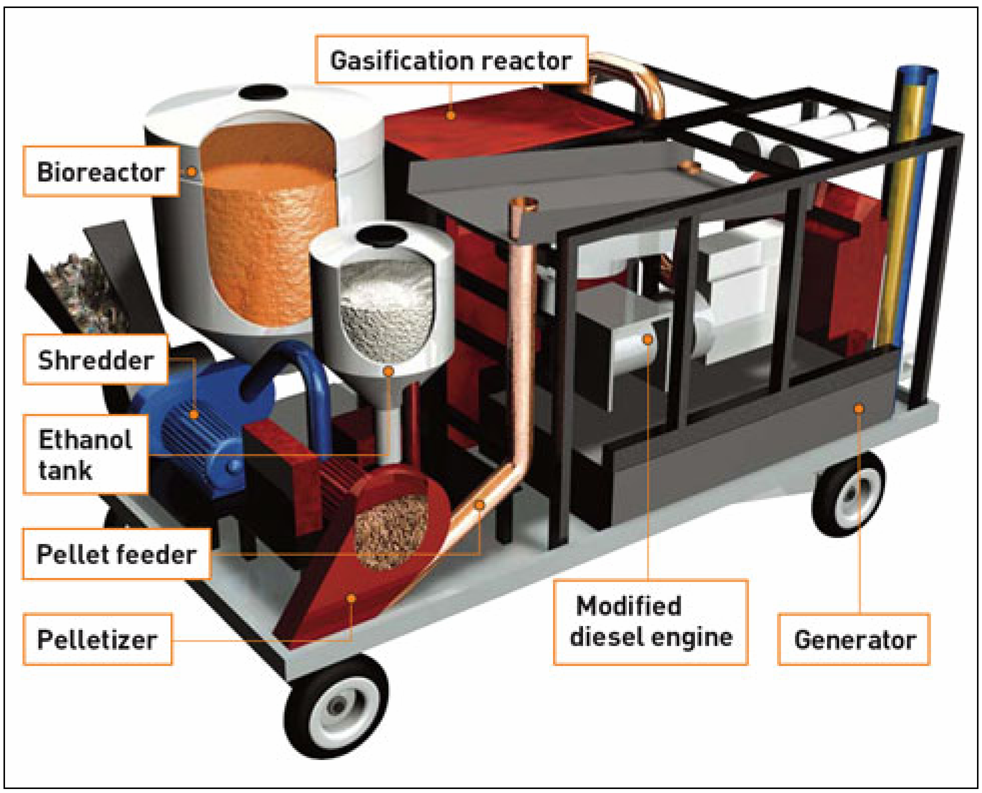

Figure 8. Tactical Garbage to Energy Refinery Diagram [From Behar, 2007]

In November 2006, researchers at Purdue University tested the first TGER prototype and found that it produced approximately 90 percent more energy than it consumed, said Jerry Warner, founder of DLSci, a private company working with Purdue researchers on the project. He said the results were better than expected. In addition to providing an alternative energy source, TGER provided a 30-to-1 reduction in waste volume (Main, 2007).

"We were lucky," says Michael Ladisch, lead Purdue researcher on the project, pointing out complex mathematical modeling that was required to ensure that all parts hummed in harmony. "We turned the key and it actually started up. That's never happened in my career before" (Hamilton, 2007).

The plan is to shrink the system by 60 percent, making it small enough to fit on a Humvee trailer. Currently, a military 5-ton truck is required to transport the bio-refinery (Hamilton, 2007).

Based on tests performed on December 31, 2006, the TGER's performance exceeds required standards with less than ten percent parasitic energy to the system (www.dlsci.com/news_include.html, 2007). The United States Army subsequently commissioned the bio-refinery upon completion of the functional prototype, and the machine is being evaluated for future Army development (Main, 2007).

4. Financial Incentives of Tactical Garbage-to-Energy Generators

Transportation of fuel to remote operating bases in hostile areas via combinations of cargo ships, aircraft sorties, and truck convoys increases the financial cost of the delivered fuel as well as the vulnerability of the escorting troops to attack by hostile forces. Food, and other necessities of combat operations, must also be delivered through the supply chain to troops in the field. The waste generated from food and packaging materials at forward bases can be used as a fuel source to offset traditional means of powering electrical generators.

The majority of savings from energy-conserving devices are not the result of direct fuel offsets, but rather a result of reduced requirements placed on the entire supply

system. Estimates of the true savings of the entire supply chain to deliver fuel to forward operating bases vary widely. Cost savings benefits as a result of the use of tactical bio-refineries are dependent on who is realizing those savings.

Consideration of the total cost of fuel delivery to remote operating bases increases the cost of each gallon of fuel considerably. Based on an estimate of 115 gallons of direct fuel offset by a TGER device at the FY2007 JP-8 fuel price, DESC would calculate the device to save $246.10 per day in fuel costs (115 gallons @ $2.14/gallon). The Army, however, would save transportation costs in excess of direct fuel savings. Previous studies have attempted to quantify the total cost of delivered fuel yielding per gallon estimates ranging from $4.40 to $20. The differences in total cost vary according to the inclusion of cost elements. Chapter V of this research provides greater detail of previous total fuel cost studies and payback calculations.

5. The Role of Department of Defense Resource Allocation and Accounting Processes in Rewarding Fuel Efficiency or Penalizing Inefficiency

Among the business world, the purpose of financial reporting is to reflect the priorities and policies of leadership and to ensure that there is tight coupling between investments and returns. However, in DoD there is weak and inaccurate linkage between allocation of resources and mission outcome, despite some prior efforts to make such a linkage. Interest in fuel and energy efficiency is largely limited to meeting federal executive orders or legislative mandates. However, since federal mandates do not apply to military weapons systems, there is neither a policy focus nor resource incentives to seek operational fuel efficiencies. Management attention, focus, and interest in fuel efficiency will result from documented analyses that quantify the military services' operational, logistics, and environmental costs of fuel use, and savings from efficiency investments.

The Planning, Programming, Budgeting, and Execution System (PPBE), DoD's budget allocation system, contains no incentive to significantly improve platform fuel efficiency. A lack of analytical tools to quantify warfighting benefits understates the contribution to capability, and Mission Needs Statements (MNSs) for platforms and

systems do not explicitly require efficiency. The subsidized fuel pricing distorts the economic picture by understating economic benefits. The consequences of no efficiency requirement and a subsidized price are that investments to improve efficiency do not compete well (or at all) in the PPBE process. The result is increased costs and degraded war-fighting capability.

Other disincentives to energy efficiency include comptroller practices that penalize commanders who reduce energy costs by reducing their budgets by the amount of savings. Funding to make platforms more efficient requires acquisition program or maintenance funding, but the impacts of these investments are the O&M accounts. In the business world this is called a "split incentive." While DoD has made progress in factoring support costs into acquisition decisions, the analysis used to determine the appropriate level of investment is hampered by the artificially low fuel price and the inability to quantify the contribution to operational capability beyond the single platform level (USD (AT&L), Improving Fuel Efficiency of Weapons Platforms, 2001).

What financial structure is currently in place to provide fuel to fighting forces? Most DoD fuel is purchased centrally through the DESC, a subcommand of DLA, via the Working Capital Fund, Defense-Wide. The DESC buys fuel in bulk and charges its customers—mainly the Services—a stabilized rate for that fuel. The rates are set at the time of the budget, over one year in advance of when the Services purchase the fuel for consumption.

The market price for fuel can fluctuate greatly between when the rates are set and when the fuel is actually moved and used. The Services buy fuel from DESC with O&M funds. If the actual cost of fuel is less than the stabilized rate, the DESC receives more money than the fuel actually costs, and future rates are adjusted to reflect the change. This rate structure simplifies accounting by allowing for minor fluctuations in actual pricing.

The problem arises when the cost of fuel greatly exceeds the stabilized rate. The rates are adjusted to reflect the change, and the services have insufficient O&M funds to fuel their vehicles and perform other functions that are paid from that budget. DoD must

delay other efforts, normally maintenance and training activities, in order to pay its utility bills, including those necessary to fuel its weapon systems. These delayed functions are lost opportunities **(**USD (AT&L), More Capable Warfighting Through Reduced Fuel Burden, 2001).

Congress provides supplemental funds when the cost of fuel far outstrips the stabilized rates that the Services use in their budget estimates. For example, the FY2006 Emergency Supplemental Act appropriated an additional amount for the Defense Working Capital Fund (DWCF), of $516.7 million. This funds $37.6 million of increased fuel costs incurred by the DWCF business area fuel consumers as a result of increased fuel prices. Costs of $107 million associated with the delivery of fuel by truck to Iraq from Kuwait and Turkey and $25 million in costs associated with the operation of the theater consolidation shipping point in Kuwait are also funded in this proposal. In addition to the $37.6 million requested here, additional funding is requested in the Service accounts to support costs associated with increased fuel prices not covered by the $2.2 billion appropriation provided in Title IX of the FY2006 Defense Appropriations Act and for costs associated with additional quantities of fuel required for the Global War on Terror (OMB, 2006).

These more realistic fuel cost projections, identifying the real cost of fuel to the operating forces and using that information to buy the optimum level of fuel efficiency can all help DoD maintain its training, weapons, and facilities maintenance. This cost accuracy improves overall readiness (USD (AT&L), More Capable Warfighting Through Reduced Fuel Burden, 2001).

6. Why Deployed Forces Should Become More Fuel Efficient

Although significant warfighting, logistics, and cost benefits occur when weapons systems are made more fuel efficient, these benefits can be subordinated to DoD requirements and acquisition processes. The war in Iraq has complicated Army and Marine Corps efforts to save fuel because the Services have added extra armor to their vehicles. Humvees with the latest armor are heavier and thus burn more fuel than those

without armor. The Army is also trading in hundreds of Humvees for larger and heavier M1117 Guardian Armored Security Vehicles, four-wheeled armored vehicles that burn more fuel (Komarow, 2006).

Military requirements documents understandably place the highest priority on performance. Focusing on this singular demand often carries a substantial provisioning and maintenance penalty. While recent DoD policy guidance has placed heavy emphasis on improved reliability, it has overlooked the substantial performance gains that can also be achieved through energy efficiencies. These include greater range, lighter-weight systems, and reduced combat vulnerability.

a. Fuel Efficiency in Warfighting System Acquisitions

When asked to describe the capability improvements that would result from better efficiency, laboratories largely focus on an individual platform, but are unable to address the broader question of how it affects the capability of the entire force. The ability to conduct these critical analyses is limited by lack of modern analytical models to quantify the efficiency benefits in terms of:

- numbers of systems needed to execute a mission
- deployment times
- sustainability for a given logistics capability
- vulnerability of the logistics tail

Energy and fuel efficiency would become a major variable in making final weapons system performance decisions if specified as a clear requirement (such as a key performance parameter) in all platforms (USD (AT&L), Improving Fuel Efficiency of Weapons Platforms, 2001). A new program to use the fully burdened cost of fuel in life cycle cost estimates and acquisition decision making is affecting the Army, Navy, and Air Force with three weapons platforms currently in development.

- Joint Light Tactical Vehicle (JLTV)
- Maritime Air and Missile Defense of Joint Forces alternative ship concepts
- Long-range strike concept decision

The program applies business process principals to quantify DoD's fully burdened cost of fuel and how to incorporate results into investment decisions. An integrated product team has been established to develop the policies and principles needed to institutionalize policy. Oversight for this pilot program is provided by the Deputy Undersecretary of Defense (Acquisition & Technology) (DiPetto, 2006).

b. Fuel Efficiency Applicability to the Principles of War

Improved warfighting capability can be directly linked to improved adherence to the following Principles of War:

- **Surprise:** Fuel efficiency increases platform stealth by diminishing the platform's heat signatures, exhaust, and/or wakes; and affords less chance of compromising movement by reducing the logistics tail and resupply communications.
- **Mass:** Fuel efficiency decreases the time required to assemble an overwhelming force by increasing the percentage of airlift, trucking, and shipping logistics that can be dedicated to troops, vehicles, and supplies instead of fuel. This creates more operational bang for the same logistical buck.
- **Efficiency**: Fuel efficiency increases commanders' flexibility in efficiently assembling an overwhelming force by reducing the percentage of logistical assets dedicated to transporting fuel. This creates the same operational bang for less logistical bucks.
- **Maneuver:** Platforms will travel faster and farther with reduced weight and smaller logistics tails that improve platform agility, loiter, and flexibility. Additionally, fuel previously consumed by electrical generators could be used for higher priority security and patrol vehicles.

- **Security:** Fuel efficiency decreases platform vulnerability to attacks on supply lines, and reduces demand for strategic reserves.
- **Simplicity:** Fuel efficiency decreases the complexity and frequency of refueling operations and logistics planning, while reducing vulnerability to the “fog of war” (USD (AT&L), More Capable Warfighting Through Reduced Fuel Burden, 2001).

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III. OPTIONS FOR ANALYSIS

A. STATUS QUO

When considering options for changing energy efficient investments, one is to continue with business as usual. Current options include not making installation infrastructure investments, requiring direct appropriation funding for energy efficient projects, and wholesale fuel pricing assumptions in weapon system O&M costing. Mandates to quantifiably increase energy efficiency may either preclude the status quo as an option or cause penalties for noncompliance. Status quo is used as a baseline in measuring the marginal return of many energy efficiency projects.

B. DOMESTIC INSTALLATIONS: CONTINUED USE OF ENERGY EFFICIENCY MECHANISMS

Already established in the processes directed by the chief White House environmental adviser, DoD is engaging energy efficiency on all fronts. The Pentagon's proposed 2008 budget includes $55 billion of installation support, including O&M, environmental projects, and child care programs. Only about $60 million of that funding is directed at energy-efficiency projects. Instead of relying on those direct appropriations, the department has been averaging about $600 million a year in share-in-savings ESPCs.

In addition to reducing demand for energy, DoD currently gets 13 percent of its electricity from renewable sources, surpassing its Congressionally-set goal of 7.5 percent. Get Moy, the Pentagon's Director of Installations, Requirements, and Management, has established an informal goal of reaching 25 percent renewable energy by 2025 (Kauffman, 2007).

Within DON, 18 Super ESPC contracts were awarded or modified between FY1999 and FY2007 for a total investment of $154.5 million, total contract prices of $370 million, and total guaranteed cost savings of $364 million. These contracts are estimated to have a cumulative energy savings of over 13 trillion Btu's (www1.eere.energy.gov, 2007).

1. Determining the Proper Return Metric-Payback versus Return on Investment

The most popular metric for measuring the success of an energy-saving project is payback. Payback is the time it takes to recoup the cost of the energy saving measures through reduced energy expenses. The most basic formula for determining simple payback is to divide the initial investment amount by annual energy savings. Several energy-saving measures have imprecise rules of thumbs for determining payback based on historical trends; controls have a two-year payback, lighting has a four-year payback, etc. (Hansen, 2003). According to DoD instructions, any energy-saving project that has a simple payback of ten years or less should be implemented (USD (AT&L), 2005).

Savings calculations based on payback alone provide a limited perspective on the full economic effects of energy conservation efforts. If energy conservation measures interfere with productivity, the resulting loss of revenue could be greater than the energy savings realized. For example, energy savings could easily be achieved by installing an underpowered winter heating system or by keeping office spaces dimly lit, but the resultant absenteeism and loss of productivity could overwhelmingly negate any energy savings. The energy payback of this project may initially be attractive, but when the impact it has on other aspects of the facility are considered, the project clearly has a negative return on investment. Owners do not buy "energy," they buy what it can do for them. To save energy effectively, it is essential to look at energy as a component of the total operation.

While the payback calculation is simple, it ignores many factors that could have a serious impact on the financial outcome of a project. Discounting for cost of capital, differences between inflation indices, and risk assessments are not addressed in the simple payback calculation, but are present in a thorough return on investment analysis. Simple payback is the time in an investment at which the undiscounted net present value is zero. The amount of time by which an investment's term extends beyond a project's payback is proportional to the ROI that project will yield. Once the initial investment is paid off, savings dividends increase the cumulative ROI of the project. Additionally, most financial lenders consider investments in terms of ROI, not payback.

Life-cycle costing (LCC) presents the net benefits of all major costs and savings for the life of the equipment discounted to present value. An energy efficiency measure that lowers the LCC without loss in performance can generally be held to be more cost effective than a cheap, poor quality alternative or a measure with a low initial cost and higher operating costs.

DoD instructions require that facilities utilize life-cycle cost analysis in making decisions about their investment in products, services, construction, and other projects to lower the federal government's costs and to reduce energy consumption. The DoD components must consider the life-cycle costs of combining projects, and encourage aggregating of energy efficient projects with renewable energy projects (USD (AT&L), 2005).

2. Additional Requirements of Energy Management Programs

Energy audits seek to determine the potential for energy savings through investment in energy efficiency. They help to identify areas for savings, mitigate uncertainty risk, and provide useful research into cost-effective efficiency measures. The requirement to make government installations more energy efficient requires the continued use of energy audits. However, energy audits are only one portion of a good energy management program. Several other factors play key roles in reducing energy consumption such as preventive maintenance, equipment calibrations, energy policy, procedures, training and control devices (Bubshait, 2003).

C. MILITARY FORWARD OPERATING BASES: USE OF WASTE-TO-ENERGY GENERATORS

An Army soldier produces an average of 7.2 pounds of trash per day. A typical 700-person Army field battalion can produce over 2.5 tons of trash a day. Self-contained, self-powered, and about the size of a small moving van, a portable refinery that efficiently converts food, paper, and plastic trash into electricity may soon be joining troops at forward operating bases in Iraq or Afghanistan (Behar, 2007; Main, 2007).

1. Possible Benefits of a Tactical Garbage-to-Energy Refinery

a. Reduced External Fuel Need

Each day, the electrical energy produced by the generator from 2,500 pounds of field waste reduces the electricity-producing fuel requirement by 115 gallons of diesel fuel. Additionally, excess thermal energy from the bio-refinery can be used for field sanitation, showers, or laundry use (Nolan, 2007).

b. Reduced Fuel Transport Costs in Money and Lives

Each month, a TGER will directly save enough gasoline to fill a mid-sized tanker truck. Less fuel trucks means less convoys and reduced exposure time to convoy operations. While a decreased fuel demand does not directly equate to fewer personnel casualties, reducing the number of fuel convoys is an objective of the Commanding General, Multi-National Force-West's request for a renewable energy source (CG, MNF-W, 2006).

c. Reduction of Fossil Fuel Exhaust Released into the Atmosphere

Much of the fuel the system combusts is carbon-neutral, said Nathan Mosier, a Purdue professor of agricultural and biological engineering involved in the project. Carbon-neutral fuels like ethanol do not cause an appreciable net increase in the atmosphere levels of the greenhouse gas carbon dioxide. This is because the fuel releases carbon that has only recently been taken up by plants during photosynthesis, the process by which plants convert carbon dioxide to oxygen and sugars. The same is not true for petroleum, in which the carbon contents were removed from the atmosphere millions of years ago (Main, 2007).

d. Increased Energy Self-sufficiency in Case of Disruption in Fuel Supply

The TGER provides enough energy to power a dining facility for a 600-person Army field unit using almost entirely the waste produced from that same unit as fuel. Such self-sustaining use of resources frees up traditional fuel supplies for other military operations (Behar, 2007).

e. Reduced Waste

In addition to providing a fuel source, the TGER provides a “twofer” by solving another problem of deployed units, reducing the logistics and costs of waste disposal (Behar, 2007).

f. Reduced Volume Resulting in Reduced Waste Disposal Cost

The TGER machine produces a very small amount of its own waste, mostly in the form of ash that the Environmental Protection Agency has designated as “benign,” or nonhazardous. Any leftover materials from the bioreactor are put into the gasifier, which has to be emptied every two to three days. The remaining waste is about enough to fill a regular-sized trash bag, and it represents about a 30-to-1 volume reduction (Main, 2007).

g. Reduced Military “Waste Signature”

By eliminating garbage remnants, the TGER could protect the unit’s security by destroying clues that such refuse could provide to the enemy (Main, 2007).

h. Compatibility with Current Equipment

The TGER was designed to be compatible with current transportation equipment and incorporates commercial-off-the-shelf (COTS) components. The TGER is skid mounted and can be employed on a military 5-ton flatbed trailer (Nolan, 2007). The generator set is the civilian version of 60KW “tactical” quiet generator, so parts, maintenance, and references are comparable (Nolan, 2007). With the exception of field trash and a trickle of diesel fuel, only one additional supply item is required. A 1.4-pound packet of biocatalyst containing enzymes and yeast is poured into the trash hopper each day. This packet is similar in appearance to laundry detergent (Nolan, 2007).

i. Model for Civilian Use Elsewhere

The TGER offers several applications outside military field use. A similar bio-refinery could be used in disaster areas. Areas affected by hurricanes, floods, or winter storms that are suffering loss of electrical and/or fuel distribution could use the

TGER to provide emergency power for rescue, health and welfare operations. TGERs could provide waste-to-energy conversion in traditional buildings as both supplemental and emergency power (Hamilton, 2007).

2. Possible Financial Savings of Utilizing Waste-to-Energy Generators

The TGER is not simply a generator that runs on bio-fuels that would have to be transported like traditional fossil fuels. The reduction of trash disposal costs offers additional financial incentives for such technologies (Behar, 2007).

While only a single prototype has been developed, current estimates suggest that the machines may cost around $1.3 million dollars each, with multiple production efficiencies as of yet undetermined. The payback periods for such machines range from a few months to several decades, depending on the way they are used and the tradeoffs they allow (Main, 2007). A possible cost learning curve chart is included in Chapter V.

Based on direct fuel costs alone, the project could have a payback period of up to 31 years. However, the best locations for the deployment of TGERs are remote areas with little established infrastructure, where military operations are of a temporary nature. One of the primary themes of a 1998 Logistics Transformation Study was that "deployment and sustainment methods and equipment must change. Ability to deploy in undeveloped areas and under unfavorable conditions must improve" (USD (AT&L), 2001).

These areas would have higher fuel transportation costs due to nonestablished or unfamiliar supply routes and few incentives to invest in long term capabilities. If total savings of the entire logistics systems are considered, each machine could pay for itself within months. Comparing per unit costs between domestic-grid derived and remote-area generated electricity is as disproportionate as comparing DESC standard fuel prices to end-to-end fuel prices. Payback analyses are included in Chapter V.

IV. METHODOLOGY FOR EVALUATING RETURN ON INVESTMENT

The return on investment in energy efficiency projects contains both quantitative and qualitative measures. This research performs the quantitative return calculations of domestic and deployed installations. The conclusions chapter contains quantitative and qualitative return comparisons. The following two sections explain the basic methodology used in determining the quantitative return on each investment. Figure 9 summarizes the methodology used in determining the return on investment for both domestic and deployed installations.

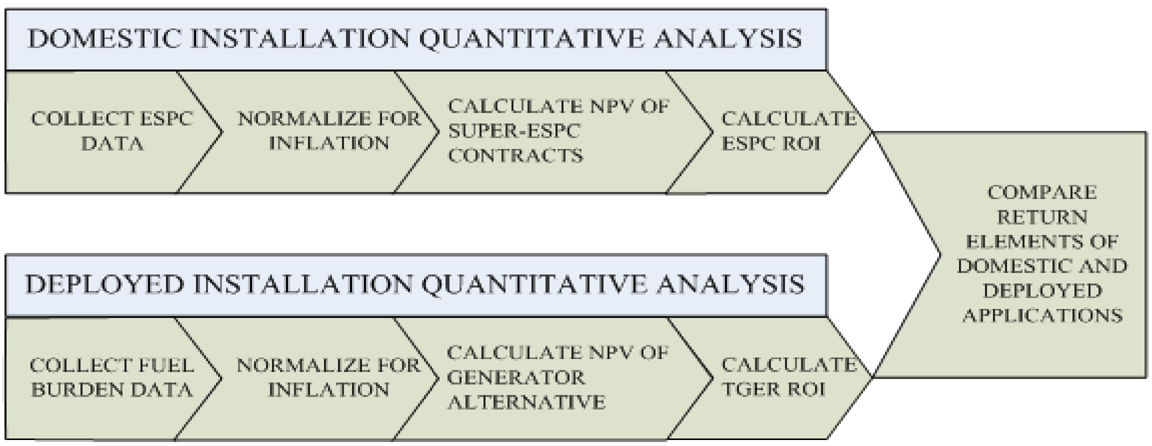

Figure 9. Return on Investment Methodology Flowchart

A. DOMESTIC INSTALLATIONS: PROJECT SAVINGS

The methodology employed in the calculation of savings returns at domestic installations includes:

- Data collection of government “super” energy saving performance contract investment amounts, contract prices, and guaranteed savings.
- Normalization of collected data to account for inflation. All dollar amounts are converted to FY2007 equivalents.
- Calculation of contract net present values.
- Calculation of return on investment for capital source and government.

B. MILITARY FORWARD OPERATING BASES: TGER SAVINGS

The methodology employed in the calculation of savings returns at deployed installations includes:

- Data collection of fully burdened cost of fuel supplies and waste disposal estimates from three previous studies.
- Normalization of collected data to account for inflation. All dollar amounts are converted to FY2007 equivalents.
- Net present value calculation of comparative life-cycle cost estimate savings.
- Calculation of system-wide return on investment.

C. ASSUMPTION OF COST VARIABILITY

One major assumption of this research is that all relevant costs of fuel delivery and waste disposal are eventually variable. While some costs may be fixed or sunk in the short term, it is assumed that if significant system-wide savings are possible over time, the variability of costs could increase to take advantage of long-term savings. Over time, equipment can be replaced, contracts can be renegotiated, and logistics procedures can be modified. It is also assumed that no economy of scale savings will be lost as a result of reduced energy consumption.

V. DATA AND COST ESTIMATES

A. ESPC SAVINGS

Between FY1998 and FY2007, 179 Super-ESPCs were issued for a total investment of $1.09 billion in government agency installation improvements. The combined guaranteed savings of these contracts is $2.68 billion, with total contract prices of $2.65 billion. All dollar amounts have been normalized to FY2007 equivalents. This section presents analysis of the financial returns of these energy performance savings contracts. Relationships between project investment, guaranteed cost savings, and contract price are quantified. Finally, contractor and government returns are compared.

The premise for using ESPCs is to provide funds that would otherwise not be available for installation energy efficiency infrastructure improvements. Private equity sources provide these funds and are compensated via utility cost savings. The extent to which these arrangements are beneficial to government agencies or the private equity sources is affected by the structure of the contract. Inflation adjusted project investment, guaranteed savings, and contract price data provide a means of determining these financial benefits.

Data were collected from government Super ESPCs between FY1998 and FY2007 (www1.eere.energy.gov, 2007). A scatter plot and regression of project investment versus guaranteed cost savings yields a predicted guaranteed cost savings estimate relative to project investment of:

$23.69M+2.23*Project Investment (FY2007$M)

This estimate is statistically significant and has a 95 percent goodness of fit with 96 percent of the variation in guaranteed cost savings explained by project investment movement. This relationship suggests that for every dollar invested in chosen energy efficiency projects, 2.23 dollars in energy utility costs are saved. Figure 10 presents these findings graphically. This data suggests that investing in energy efficiency has the potential for positive financial returns over the life of the investment.

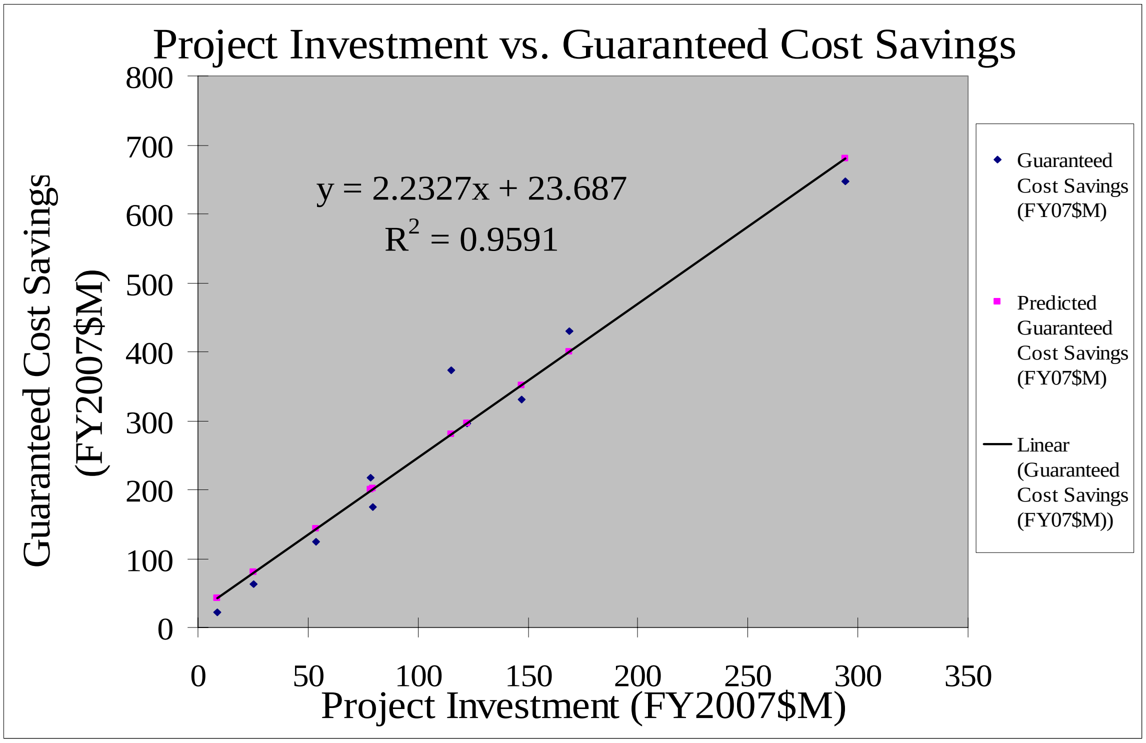

Figure 10. Super ESPC Project Investment versus Guaranteed Savings

Given the analysis above that shows that there are potential savings, there are three options available for government agency energy efficiency projects:

- Status quo – make no infrastructure improvements and yield no utility savings relative to current usage.
- Self-invest – pay for infrastructure improvements via direct appropriation, government agency reaps utility savings over several years.
- Energy savings performance contracts/contracting (ESPCs) – private equity funds improvements, utility savings compensate private equity funding according to contract terms.

Each funding option is used frequently according to energy savings potentials and available funding. Energy intensity mandates create a demand to improve energy efficiency and may preclude the status quo as an option. Given the need for energy efficient projects and lean appropriation budgets, public funding for installation self-investment may not be available. The remaining option is ESPC.

ESPCs have pros and cons. On the positive side, they provide additional funds for installation improvements that would not otherwise be available. Additionally, guaranteed savings are structured so as to make the government better off with the contract than without it, as well as transferring some risk of future utility rate increases to the lender. The government's financial benefit of the Super ESPCs can be quantified by looking at past examples. For all government super ESPCs issued from 1998 to 2007, the government is contracted to save a total of $27 million with the contracts relative to status quo through the term of the contracts. However, during this same period, lenders will receive the bulk of the utility savings. Of the forecasted $2.68 billion in utility savings, $1.09 billion will repay initial project investments, leaving $1.59 billion transferred to the private equity lenders as net income. While the government benefits from this arrangement via reduced energy usage relative to status quo and assistance in complying with EO 13423, vendors have significant financial incentives. Returns on investment for equity lenders range from 116 to 224 percent over the life of the contract. If the government chose to fund the projects and was able to reproduce the program management and other behaviors of these commercial vendors, it may have realized a $1.59 billion savings after repaying all project investment costs. Table 4 displays government and contractor savings and ROI data for all government Super-ESPCs from 1998 to 2007 (www1.eere.energy.gov, 2007).

All $ figures in FY07$M	Project Investment	Contract Price	Guaranteed Cost Savings	Contractor Net	Contractor ROI	Govt Net (w/contract)	Govt Net (self invest)	Govt ROI (self invest)
Total for FY 1998	9	20	23	11	127%	3	14	160%
Total for FY 1999	53	123	125	70	131%	1	71	133%
Total for FY 2000	80	174	175	94	119%	1	96	120%
Total for FY 2001	147	335	330	188	128%	-4	183	125%
Total for FY 2002	115	373	373	257	224%	1	258	224%
Total for FY 2003	294	635	647	341	116%	12	352	120%
Total for FY 2004	25	59	62	34	134%	3	37	146%
Total for FY 2005	79	217	217	138	175%	0	138	176%
Total for FY 2006	169	425	430	256	151%	5	261	155%
Total for FY 2007	122	291	296	169	138%	4	173	142%
Total all years	1,093	2,651	2,678	1,558	143%	27	1,585	145%

Project Investment:	Amount invested in facility improvements
Contract Price:	Contract cost to government
Guaranteed Cost Savings:	Reduction in energy/utility costs over length of contract
Contractor Net:	Difference between contract price and project investment
Contractor ROI:	Contractor return on investment (contractor net divided by project investment)
Govt net (w/contract):	Guaranteed cost savings less contract price
Govt net (self invest);	Guaranteed cost savings less project investment
Govt (self invest) ROI:	Govt net (self invest) divided by project investment

Table 4. All Government Super ESPC Data FY1998-FY2007 [After: www1.eere.energy.gov, 2007]

B. TOTAL DELIVERED FUEL DATA FROM PREVIOUS STUDIES

Recent studies have sought to quantify the total cost of fuel delivered to military forward operating bases. Three studies that this research references are:

- Burdened Cost of Fuel, Office of the Secretary of Defense (Program Analysis and Evaluation), August 2006.
- An Analysis of the Energy Potential of Waste in the Field, Logistics Management Institute, February 2004.
- Sustain the Mission Project: Resource Costing and Cost-Benefit Analysis, Army Environmental Policy Institute, July 2006.

1. Summary of Burdened Fuel and Waste Cost Estimates

Table 5 summarizes the results of the referenced studies. The LMI study makes a cost distinction between the brigade- and battalion-level costs, while the other two studies do not specifically detail how such costs may vary. Selection of comparatively

appropriate models has attempted to enable sufficient commonality for equating battalion-level costs. These figures are used as the basis for determining operations and maintenance life cycle cost estimates for a waste-to-energy generator. The standard fuel price of $2.14 per gallon is used as the unburdened cost of fuel and $69 per ton is considered the unburdened waste disposal cost.

	Burdened Cost of Fuel	**Burdened Cost of Waste Disposal**
OSD(PA&E) Study	**$5.54/gal**	**n/a**
LMI Study	**$20/gal**	**$975/ton**
SMP Model	**$6.40/gal**	**n/a-**

Table 5. Summary of Delivered Fuel and Waste Disposal Cost Estimates

The following sections describe the basic methodologies of each study. The data from these studies are used as fully burdened fuel cost estimates in subsequent analyses. Since the studies occurred in different years, each estimate is first presented in then year dollars and then converted to FY2007 dollar estimates for comparability.

2. Office of the Secretary of Defense (Program Analysis and Evaluation) (OSD (PA&E)): Burdened Cost of Fuel

This OSD (PA&E) study (OSD study) estimates the costs of fuel delivery using the DESC standard price as a starting point and adds the costs incurred in retail fuel delivery such as:

- Primary Fuel Delivery Asset O&S
- Primary Fuel Delivery Asset Depreciation
- Direct Ground Fuel Infrastructure O&S
- Indirect Base infrastructure O&S
- Nominal Environmental Cost
- Other Service/Delivery Specific Costs

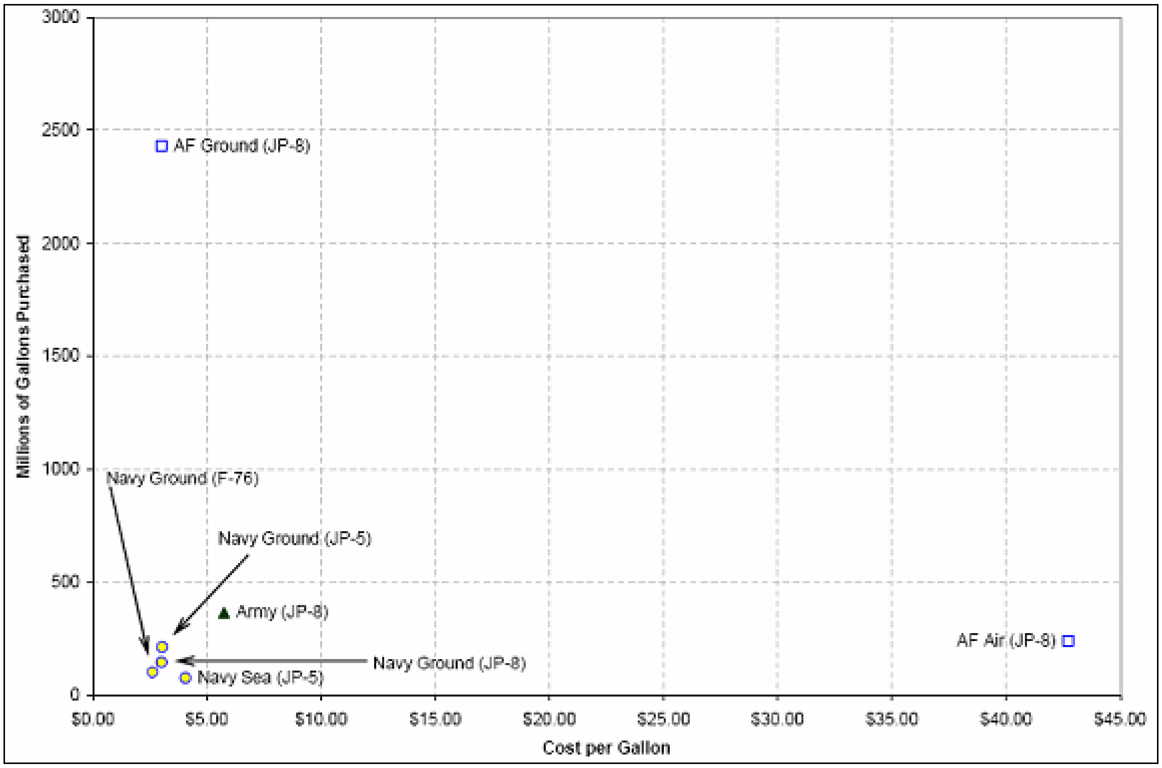

Figure 11. Military Burdened Fuel Cost by Service and Consumption [From OSD (PA&E), 2006]

The OSD study examines delivered fuel costs of each military service as illustrated in Figure 11. The model of this research is based on TGER placement at an Army battalion and thus focuses on those portions of the study applicable to the Army. Based on the above cost elements and the determination that the primary fuel delivery method is via ground vehicles, the 2006 burdened cost of fuel for Army JP-8 is calculated as follows:

- Standard Fuel Price Per Gallon $2.53
- O&S of Fuel Trucks/Trailers (including personnel) $3.13
- Fuel Truck/Trailer Depreciation $0.09
- Base Infrastructure Costs unknown
- Environmental Costs $0.10
- Total Cost Per Gallon: $5.85
-

Converting the FY2006 estimate to an FY2007 estimate yields the following:

- Standard Price per gallon (published 2007 price) $2.14
- O&S of Fuel Trucks/Trailers (including personnel) $3.21
- Fuel Truck/Trailer Depreciation $0.09
- Base Infrastructure Costs unknown
- Environmental Costs $0.10
- Total Cost Per Gallon: $5.54

This estimate of $5.54 per gallon represents FY2007 generic peacetime costs, which can increase according to mission and security escort requirements (OSD (PA&E), 2006).

3. Logistics Management Institute: An Analysis of the Energy Potential of Waste in the Field

The LMI study estimates the amount and makeup of waste in an operating theater, analyzes the logistics of waste disposal and fuel supply there, and estimates the value of a process for converting waste into fuel. In characterizing military waste, the study gathered data at the National Training Center in Fort Irwin, California. Estimates of typical waste streams for a Stryker Brigade Combat Team (SBCT) over a continuous 30-day period were developed based on actual waste streams of units conducting field condition exercises. The SBCT is the most modern fighting unit within the United States Army, so it provides an excellent source of data for the amounts and types of waste that future Army units are likely to produce. To assess waste disposal in the field, this study examined open literature and conducted interviews with field personnel. Although little hard data on field waste disposal exists, extensive anecdotal information suggests that such disposal sometimes can be troublesome for U.S. forces.

The LMI study's analysis of the logistics of waste disposal accounts for the personnel, trucks, fuel, and other equipment needed. It also considers how these logistics change as military units pick up and transport waste from different points in an operating theater. Finally, this study addresses logistics costs in order to estimate the value of reducing waste through transforming it into fuel.

In a 2001 report, the Defense Science Board (DSB) estimated the cost to transport fuel to and within an operating theater. The LMI study borrows those costs to estimate the value of fuel produced at different points within a theater.

a. Cost of Waste Disposal

Based on the LMI study of current and past waste disposal practices by deployed Army troops, estimates of potential savings from converting waste into fuel include the following:

- The estimated costs of disposal in a Middle Eastern theater vary between \$62 and \$903 per ton, depending on how far the waste must be transported for disposal.
- According to a Defense Science Board study, it costs DoD \$13 per gallon to deliver fuel to an in-theater base support depot. From there, the costs rise with distance to any distribution point.

In estimating the cost of waste disposal for a Middle Eastern operation at the corps, division, brigade, and battalion levels, the assumption is made that all the waste generated in the theater is picked up and disposed of behind the lines. Troops in the midst of a conflict often are forced to bury or burn waste on the spot, but after a conflict is resolved and troops remain in place, the waste is likely to be collected.

Basic assumptions of this model are as follows:

- Cost of truck—A standard U.S. Army M931, 6x6, 5-ton truck is capable of carrying 30.5 cubic yards (approximately 2.82 tons), while achieving 4.1 mpg in open road driving. We assume that its average speed in trash transport duty is 30 mph. Such a truck costs about \$128,000, and will travel approximately 68,000 miles over a 20-year lifetime, implying an amortization rate of \$1.88 per mile.

- Cost of soldiers—The fully loaded average pay of two soldiers (one a private first class and the other a private/E-2) is $18.40 per hour. We assume the soldiers are on the truck during its entire trip and also spend one hour loading and unloading trash.
- Cost of fuel—The cost of JP-8 is $13 per gallon at the point of entry.
- Cost of waste disposal—The U.S. average cost multiplied by a local adjustment factor.
- Waste per man per day—Estimated at 7.2 pounds using the Fort Irwin data.

This last assumption allows for a calculation of the daily amounts of waste for each Army unit:

- Battalion—2.5 tons
- Brigade—12.6 tons
- Division—50.4 tons
- Corps—201.6 tons

Since no data was available on the cost of disposing of waste in overseas locations, the chosen starting point is the average cost in the United States in 2003, $34.06 per ton. The Army Corps of Engineers has published a list of Local Adjustment Factors that provides relative costs of construction (compared to the United States) in many countries around the world. For this analysis, the assumption is made that relative trash disposal costs are similar to these relative construction costs.

The Army Corps of Engineers provides adjustment factors for only two Middle Eastern countries: Oman and Bahrain. The factors for these countries are 1.58 and 2.07, respectively. Using an average of the two, an adjustment factor for the Middle East would be 1.825, which means that the cost of disposing of a ton of solid waste in a Middle East theater would be $62.16, which is rounded to $62 for simplicity. The distance between the division and corps support areas is 124 miles. Thus, trucks would travel 248 miles to pickup and deliver trash to that point. The cost of this operation would be as follows:

- Truck—248 miles at \$1.88 per mile = \$466 per trip to carry 2.82 tons
- Soldiers—2 soldiers at \$18.40 per hour times 9.27 hours = \$341
- Fuel—248 miles ÷ 4.1 mpg × \$13 per gallon = \$786
- Disposal—\$62 per ton

Divide the first three numbers by 2.82 to derive a per ton cost, and then add \$62, yielding a total cost of waste disposal generated at the division level of approximately \$629 per ton. Continuing this cost allocation to the brigade and battalion levels yields corresponding cost increases as shown in Table 6.

Cost Category	**Corps**	**Division**	**Brigade**	**Battalion**
Truck	-	166	199	**248**
Soldiers	-	121	143	**170**
Fuel	-	280	334	**418**
Disposal	62	62	62	**62**
Total	62	629	738	**898**

Table 6. Waste Disposal Costs in a Middle Eastern Operating Theater (\$/ton) [From LMI, 2004]

These estimates provide a basis for determining the value of transforming waste generated at various points along the supply chain into fuel. Simple reasoning implies that a ton of waste transformed into fuel is a ton of waste not subjected to transport and disposition.

Assuming the 2004 waste disposal costs are in 2004 dollar amounts, the cost of battalion-level waste disposal in 2007 is approximately \$975 per ton.

b. Cost of Fuel Delivery

The DSB study cites work done by the Army Research Laboratory, which calculated a typical cost for fuel delivered to an in-theater support depot of \$13/gallon. The DSB provided an estimate of the cost of moving fuel from a support depot toward the front lines. It found that moving fuel by heavy truck (5,000 gallons on a Heavy

Expanded Mobility Tactical Truck (HEMMT)) costs about $50 per kilometer. It also found that movement by helicopter is many times more expensive, as much as $400 per gallon for 1,500 gallons delivered 600 kilometers, for example.

The LMI study assumes that fuel is moved by truck to various points along the supply chain. The Corps Support Area is assumed coincident with the initial supply depot, and other support areas are forward from there. Given the DSB estimate of $50 per kilometer, the 2004 estimated cost of delivered fuel would be as follows:

- Corps—$13 per gallon
- Division—$17 per gallon
- Brigade—$18 per gallon
- Battalion—$19 per gallon

Adjusting for inflation from 2004 to 2007, the 2007 estimated costs of delivered fuel are:

- Corps—$14 per gallon
- Division—$18 per gallon
- Brigade—$19 per gallon
- Battalion—$20 per gallon

These costs provide a means to estimate the value of fuel produced by a waste-to-energy process within a theater. It can be reasoned that a gallon of fuel produced on site is one less gallon that has to be brought to the theater and distributed there.

4. Army Environmental Policy Institute Report "Sustain the Mission Project: Resource Costing and Cost-Benefit Analysis"

The first step in development of the Sustain the Mission Project (SMP) costing model was to identify the key cost elements that come into play in the consumption of energy. The SMP fuel cost elements are comprised of four categories:

- the fuel commodity
- the materiel required for distribution, storage, and quality control of the commodity

- the logistical infrastructure, including port handling and intra- and inter-theater transport costs, considered for both military deployment and contractor resupply scenarios
- support services, or the military personnel tasked with supplying the commodity.

These cost elements are summarized in Table 6. The SMP model does not consider force protection for delivery of the fuel, although these factors could certainly be included in future analyses, and some likely should.

Figure 12 portrays the potential journeys fuel may undertake in contingency operations. Along each leg of the journey, different costs come into play that correspond with the cost elements identified above. There are two basic pathways for energy: one begins at the U.S. base of operations and covers the full distance to the point of use; the other begins in-theater at a prepositioned supply or local source, thus incurring fewer costs in transport. The SMP cost methodology considers these potential journeys in order to cost out the relevant cost elements according to varying scenarios.

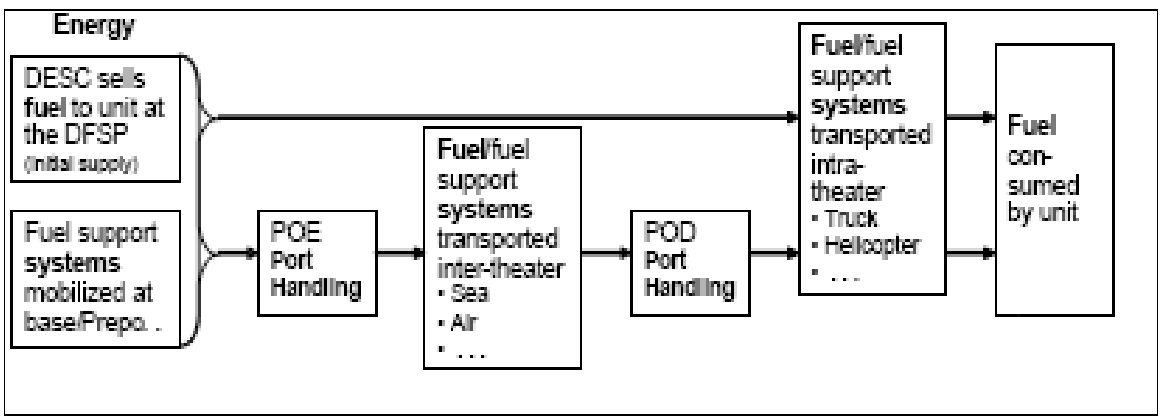

Figure 12. SMP Contingency Operation Fuel Journey [From AEPI, 2006]

After identifying the cost elements, the next step was to define the actual items populating each cost element category. For this step, the SMP authors sought out Subject Matter Experts (SMEs) in the Army logistics, costing, force development, and installation communities.

The fuel commodity cost element is simply the gallon of Jet Propellant-8 (standard kerosene jet fuel [JP-8]), diesel fuel, or gasoline that is purchased by the Army from DESC at the training base or at a Defense Fuel Supply Point (DFSP) in theater. For the SMP cost model, it was assumed that all fuel consumed consisted of JP-8, for simplicity.

DESC was consulted for the supply scenario for fuel in contingency operations. The SMP cost methodology is based on the assumption that DESC maintains a DFSP both at the case study training base site, and in the case study theater. DESC absorbs all costs of delivering the fuel to the base or theater and the Army pays only the standard price set by DESC. This wholesale refinery price was used to cost out the fuel commodity cost element.

The fuel support items cost element comprises the materiel required to distribute and store fuel as well as produce energy. Such support items include refueling equipment, pipeline construction equipment, filters, hoses, storage drums, tanker trucks, and pumps. Of equal importance are generator sets, which the Army depends on for mobile power generation in the field. This research does not consider TGER savings internal to the SMP model.

The port handling cost element applies only to contingency operations. Port handling fees are calculated per measurement-ton, and differ according to the type of item being transported. Port handling is charged both at the point of embarkation (POE) and the point of debarkation (POD).

The inter- and intra-theater transport cost element applies to contingency operations and includes the delivery of fuel from the DFSP to the point of use, and the delivery of fuel support items from the training base or prepositioned supply depot to the point of use. The SMP cost model is based on the assumption that the Army purchases fuel from the DESC at a given location, and then transports it by military vehicle to the stationing area. Fuel is then resupplied throughout the periods of deployment and redeployment in theater by either contract vehicle or, in case of rough terrain or tactical necessities, Chinook helicopter. In the SMP methodology, the fuel support items are

transported only once inter-theater during initial deployment, and are redeployed intra-theater a varying number of times and distances. Cost of transport by sea is based on a flat rate per measurement ton figure; by military or contract truck is based on a dollar per short-ton per mile rate; and by Chinook is based on a dollar per short-ton per hour rate.

The fuel support services cost element applies to contingency operations, and represents the military personnel whose primary responsibility is supplying fuel to the unit in the theater. The number of personnel tasked with fuel storage, distribution, and related activities were costed out according to their Continental U.S. (CONUS) basic pay and allowances plus Special, Incentive, and Hazardous Duty Pays. The SMP methodology does not include personnel costing in the analysis of the training base, but it is worth noting that future work might consider costing out the military occupational specialty (MOS) training activities that are associated with fuel support services. It should be noted that assigning costs to a personnel category is a dicey business, because of sunk costs and shared duties. For example, engineer battalions carry out construction of pipelines for fuel, but are primarily involved in activities not related to energy supply. Because of this issue, it was necessary for the current SMP methodology to narrow the personnel factor down to the smallest common denominator to avoid the inclusion of sunk costs.

For the purposes of the SMP methodology demonstration, three scenarios were developed to demonstrate the range of costs that are possible when including the cost elements. These three scenarios represent the low cost, medium cost, and high cost estimates of fuel delivery. For simplicity in this research, the medium-cost scenario from the SMP model will be used for comparison purposes. The costs of this scenario are illustrated in Figure 13 and assume the following delivery characteristics:

- Contractor resupply of fuel during established military operations
- 150 miles roundtrip per delivery
- 180 trips per year
- 50 percent of fuel is delivered by truck
- 50 percent is delivered by Chinook helicopter due to difficult terrain

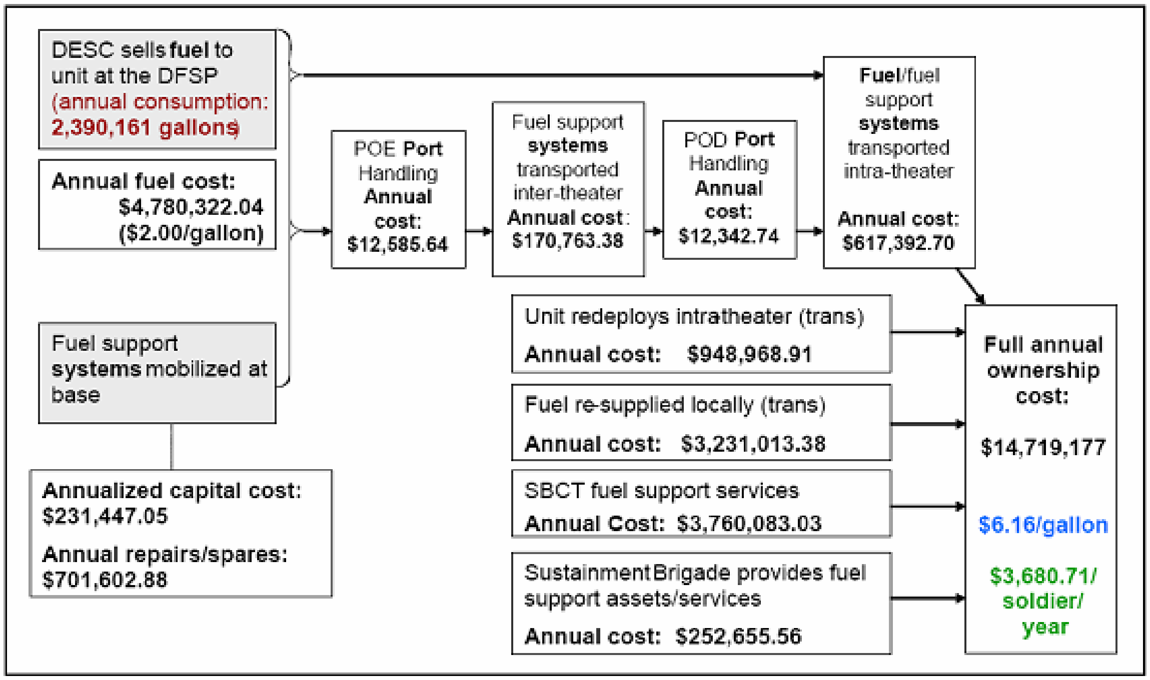

Figure 13. Medium-cost Scenario Results for the Stryker Brigade Combat Team's Energy Use in Contingency Operations [From AEPI, 2006]

In converting the 2006 SMP study to 2007 dollars, the fuel commodity price is adjusted from $2 per gallon to $2.14 per gallon as per the published DESC standard fuel cost. All other costs are adjusted according to O&M indices. This conversion yields the following 2007 estimate:

Fuel Commodity (2,390,161 gallons @ $2.14/gallon)	$5,114,945
All Other O&M costs (9,938,855*1.0250 inflation factor)	$10,187,326
Full Annual Ownership Cost	$15,302,271
Burdened Cost per Gallon (based on 2,390,161 gallons)	$6.40

C. LIFE CYCLE COST COMPARISON OF A WASTE-TO-ENERGY GENERATOR VERSUS A STANDARD FIELD GENERATOR

1. Life Cycle Cost Estimate (LCCE) Assumptions

For purposes of this comparison, the performance of a TGER unit is considered to be an acceptable substitute for generator sets currently used in operating environments.

All elements of military generator requirements are assumed to be met. These qualities include ruggedness, ease of maintenance, reliability, transportability, series/parallel configuration, and power quality at extreme temperatures and altitudes. Additional assumptions of this model include:

- "laundry packet" of bioreactor enzymes incurs a negligible cost
- one TGER is capable of processing 2,500 pounds of convertible waste per day creating a direct fuel offset of 115 gallons
- TGER prototype is able to be reproduced in a reasonable time

2. Generator Life-Cycle Cost Estimates (LCCE)

LCCE of currently used generators and a prototype waste-to-energy generator illustrate the total production cost of each system. For this example, both generators will be assumed to be operated by an Army battalion deployed to a nonpermanent forward operating base in the Middle East. The following costs estimates are based on analogous systems and expert opinion.

a. Initial Cost Comparison

A standard 60-kilowatt field generator set (NSN 6115-01-317-2134) is currently available to field commanders at a price of $25,063 (Army Natick, 2007). The first prototype TGER had a cost of $1.5 million, not including $0.3 million of Army-funded program and engineering support or $0.4 million of assessment support. The second TGER has an expert opinion estimated production cost of $1.3 million (all dollar figures are FY2007$). If the same rate of learning occurs in subsequent units, an 87 percent learning curve approximates expected production efficiencies. Figure 14 represents a hypothetical production learning curve for the first ten TGER units. Assuming learning at this rate continues indefinitely, the purchase price of the standard generator set will be below TGER individual unit production costs until the 699,725,122nd TGER is produced. At this production level, the average TGER unit cost will still exceed the standard 60-kilowatt generator price by $6,301. Such production

levels are several orders of magnitude above any realistic expectations for TGER production, but illustrate that the value of such a system will not be found in initial generator procurement cost savings.

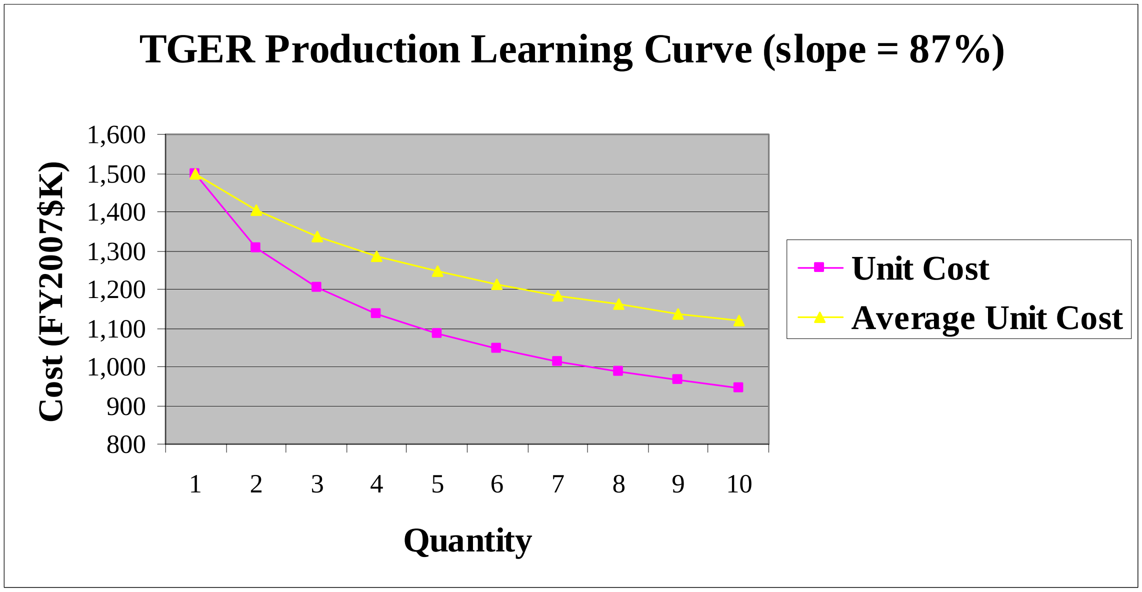

Figure 14. Theoretical TGER Production Learning Curve

There is a possibility that TGER components external to the generator may have a life expectancy beyond that of the replaceable onboard generator set. While specific component life spans may provide for system extensions without the need for total system replacement, there is not yet enough known about specific components to warrant separate life-cycle estimates. Accordingly, the entire TGER system is assumed to have a uniform system-wide life expectancy. The possible increased life expectancy of those components is assumed to offset disposal costs in excess of a standard generator, thus, disposal costs are not included as a source of additional cost or savings.

In presenting comparative cost estimates, two figures will be used to predict the initial cost of fielded TGERs. For the conservative estimate, per unit cost will be held constant at $1.3 million; however, much of the embedded cost of the first prototypes was used for research and development efforts and not purely manufacturing. Experts familiar with the system estimate that production models beyond the second

prototype could be produced for as little as $300,000 each. If the learning curve cost reduction model holds, the average unit price will reach $300,000 after the production of the 9,200th unit. Given the significant difference between initial cost estimates and the possibility of nonproduction costs in prototype development figures, LCCE and return calculations will consider both estimates separately.

b. Operation and Maintenance Life Cycle Cost Estimates (LCCEs)

Since cost avoidance and savings are not found in the initial procurement phase of a TGER life-cycle, estimates of O&M life-cycle costs must be examined. Additionally, a complete LCCE includes O&M costs. The following O&M cost estimates focus on the marginal cost differences between a traditionally fueled generator and a waste-to-energy generator. As mentioned in the overall assumptions, the maintenance requirements, reliability, and performance of each option are assumed to be equivalent. Cost elements that are common and assumed equivalent to each option are not included in the cost savings estimate. The cost elements included vary according to which study is referenced; all previous studies include a burdened cost of fuel, but only one also considers waste disposal. All dollar amounts are inflation normalized to FY2007 dollars.

Life expectancy estimates of field generators vary significantly. Warranty coverage for a standard 60kW generator covers the lesser of 36 months or 1,800 operating hours (Marine Corps Systems Command, 2006). If operated continuously, a generator could consume its warranty coverage within 75 days, although it is expected that a generator will perform well beyond its warranty period. Estimates for actual operating life range from 10,000 hours (1.14 years continuous) to ten years with proper maintenance. Given such a wide range of life expectancy, O&M life-cycle estimates from 1 to 10 years are prepared with associated returns for each time period. Given the more costly initial procurement cost, O&M savings yield a greater return as life expectancy increases. Table 7 presents annual O&M life-cycle cost savings estimates for each burdened fuel/waste cost study, along with unburdened fuel savings. Figure 15 presents cumulative operating savings of each cost element.

Time Period (Years)	1	2	3	4	5	6	7	8	9	10	Totals
LMI Model	Fuel cost per gallon:			20	Waste disposal cost per ton:					975	
Period O&M Savings	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	12,843
Fully Burdened Fuel Savings	840	840	840	840	840	840	840	840	840	840	8,395
Waste Disposal Savings	445	445	445	445	445	445	445	445	445	445	4,448
SMP Model	Fuel cost per gallon:			6.40	Waste disposal cost per ton:					0	
Period O&M Savings	269	269	269	269	269	269	269	269	269	269	2,686
Fully Burdened Fuel Savings	269	269	269	269	269	269	269	269	269	269	2,686
Waste Disposal Savings	0	0	0	0	0	0	0	0	0	0	0
OSD(PA&E) Model	Fuel cost per gallon:			5.54	Waste disposal cost per ton:					0	
Period O&M Savings	233	233	233	233	233	233	233	233	233	233	2,325
Fully Burdened Fuel Savings	233	233	233	233	233	233	233	233	233	233	2,325
Waste Disposal Savings	0	0	0	0	0	0	0	0	0	0	0
Unburdened	Fuel cost per gallon:			2.14	Waste disposal cost per ton:					0	
Period O&M Savings	90	90	90	90	90	90	90	90	90	90	898
Fully Burdened Fuel Savings	90	90	90	90	90	90	90	90	90	90	898
Waste Disposal Savings	0	0	0	0	0	0	0	0	0	0	0
Savings figures in FY07$K, per unit costs in FY07$											

Table 7. Annual TGER O&M Fuel and Waste Disposal Savings

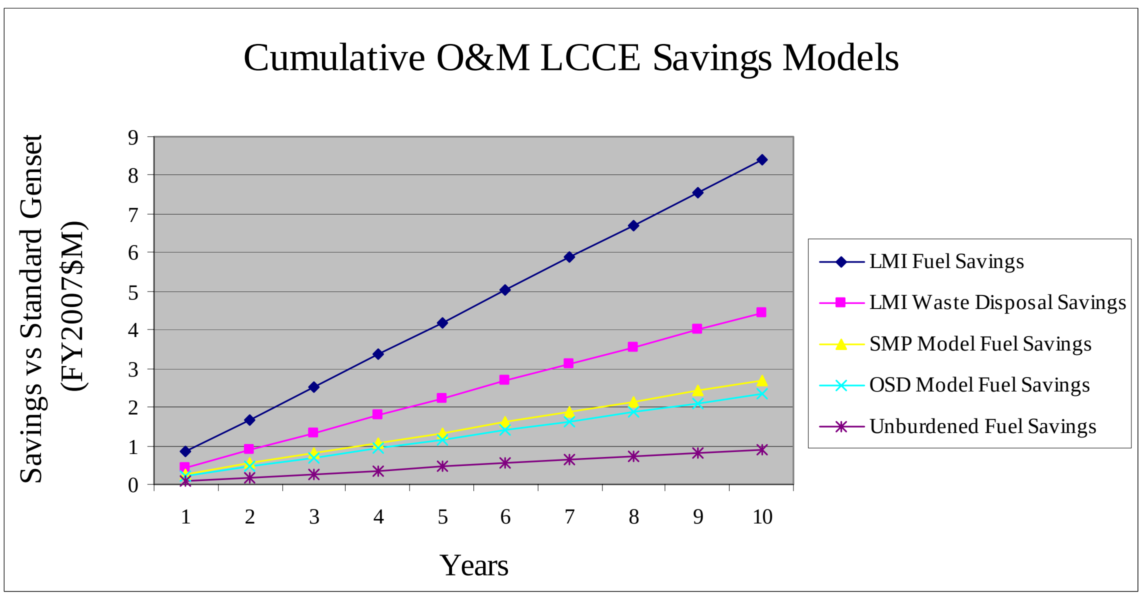

Figure 15. Cumulative O&M LCCE Savings

c. Project Return on Investment

Given initial cost data and expected O&M savings, the ROI for a specific generator life expectancy can be determined. In this case, investment and savings are measured relative to a standard generator set, so initial investment is calculated as the cost of a TGER in excess of a standard generator set. Return is measured by subtracting 1 from the quotient of operating savings divided by investment [(operating savings/investment)-1]. Table 8 summarizes cumulative savings and returns based on a TGER initial cost of $1.3M. Table 9 provides the same information for TGER initial cost of $300K. Returns are overall and not annualized. Combinations of generator life expectancy and operating savings models that have a negative return are below the thick line. Based on ROI, any combination above the line has the potential for overall cost savings when compared to the status quo.

All dollar figures in FY07K$										
Time Period (Years)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment (initial cost difference)	1,275									
Cumulative LMI Operating Savings	1,284	2,569	3,853	5,137	6,422	7,706	8,990	10,275	11,559	12,843
LMI Model ROI	1%	101%	202%	303%	404%	504%	605%	706%	807%	907%
Cumulative SMP Operating Savings	269	537	806	1,075	1,343	1,612	1,880	2,149	2,418	2,686
SMP Model ROI	-79%	-58%	-37%	-16%	5%	26%	47%	69%	90%	111%
Cumulative OSD Operating Savings	233	465	698	930	1,163	1,395	1,628	1,860	2,093	2,325
OSD Model ROI	-82%	-64%	-45%	-27%	-9%	9%	28%	46%	64%	82%
Cumulative Unburdened Operating Savings	90	180	269	359	449	539	629	719	808	898
Unburdened ROI	-93%	-86%	-79%	-72%	-65%	-58%	-51%	-44%	-37%	-30%

Table 8. Cumulative Operating Savings and Comparative ROIs (TGER @ $1.3)

All dollar figures in FY07K$										
Time Period (Years)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment (initial cost difference)	275									
Cumulative LMI Operating Savings	1,284	2,569	3,853	5,137	6,422	7,706	8,990	10,275	11,559	12,843
LMI Model ROI	367%	834%	1301%	1769%	2236%	2703%	3170%	3637%	4104%	4571%
Cumulative SMP Operating Savings	269	537	806	1,075	1,343	1,612	1,880	2,149	2,418	2,686
SMP Model ROI	-2%	95%	193%	291%	389%	486%	584%	682%	779%	877%
Cumulative OSD Operating Savings	233	465	698	930	1,163	1,395	1,628	1,860	2,093	2,325
OSD Model ROI	-15%	69%	154%	238%	323%	407%	492%	577%	661%	746%
Cumulative Unburdened Operating Savings	90	180	269	359	449	539	629	719	808	898
Unburdened ROI	-67%	-35%	-2%	31%	63%	96%	129%	161%	194%	227%

Table 9. Cumulative Operating Savings and Comparative ROIs (TGER @ $300K)

3. TGER Payback Calculations

Figure 16 illustrates the simple payback periods for a TGER device with a purchase price of $1.3 million. Based on unburdened waste disposal costs of $69 per ton and unburdened fuel costs of $2.14 per gallon, unburdened payback periods considering waste only, fuel only, and waste and fuel savings are 41, 14, and 11 years, respectively. Using the LMI study fully burdened cost estimates of $20 per fuel gallon and $975 per ton of waste, cost savings for each category yield payback periods of 2.9, 1.5 and 1 years. Figure 17 illustrates payback periods based on a $300,000 purchase price. These charts present the extremes of payback possibilities based on unburdened costs and the highest cited study. Paybacks based on OSD and SMP fuel burden cost models are between these extremes. While ROI provides a more detailed analysis of options, some DoD instructions cite payback as an investment decision metric. These figures are provided to demonstrate the impact of considering burden costs in fuel and waste cost decisions.

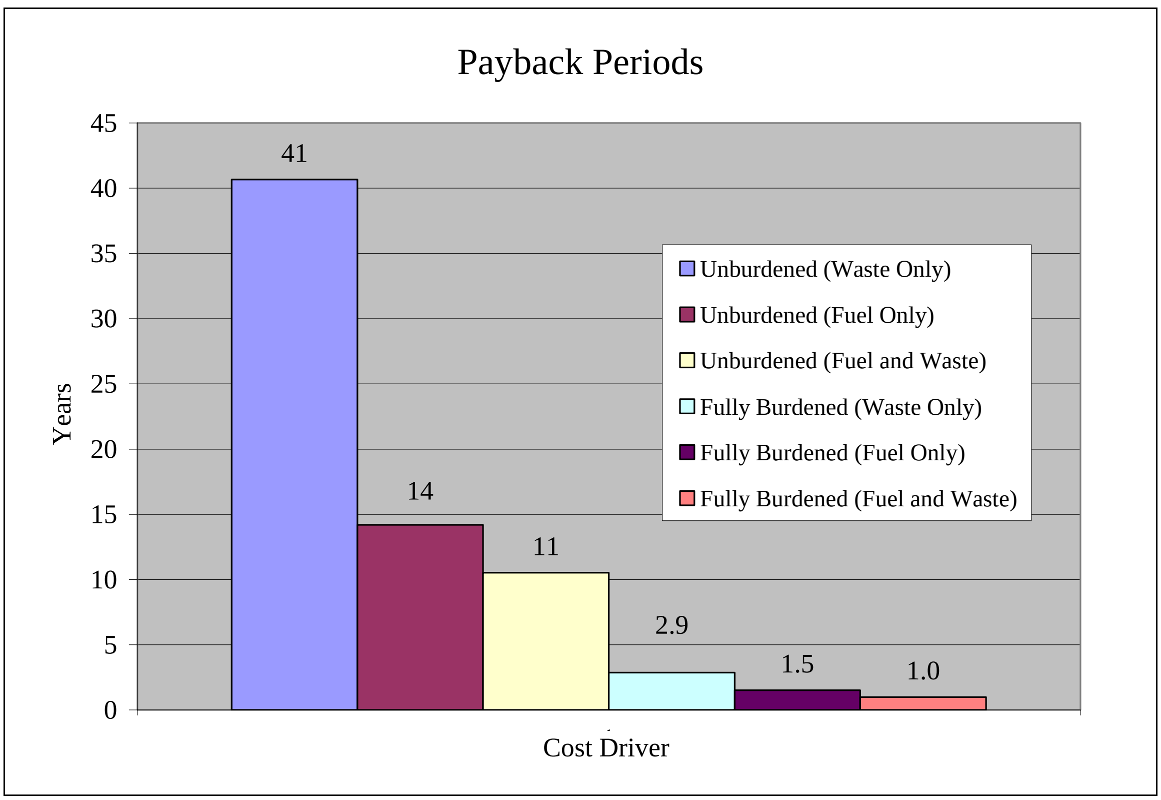

Figure 16. TGER Payback Periods ($1.3M initial cost)

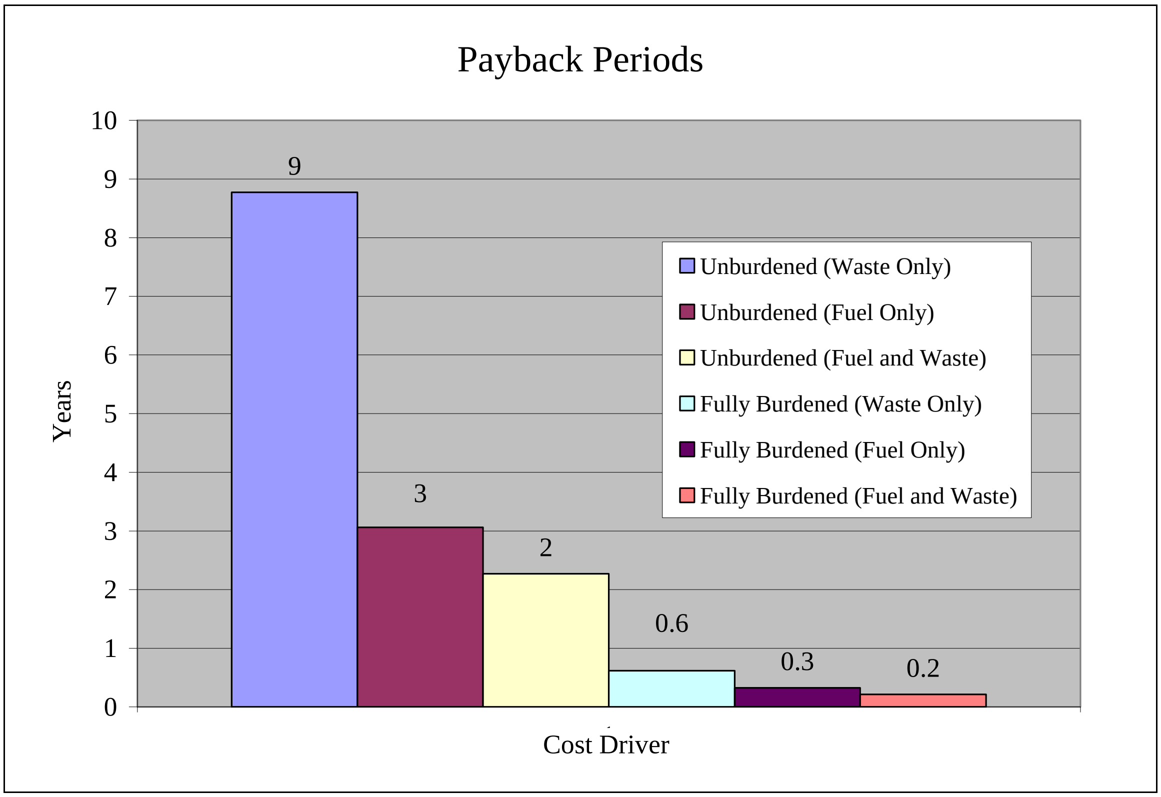

Figure 17. TGER Payback Periods ($300K initial cost)

VI. OBSERVATIONS

A. SOCIAL AND POLITICAL ENVIRONMENT

"[Exxon has] placed a very large bet with shareholders' money that the world will remain addicted to fossil fuels, and they're not ready for a more carbon-constrained world," according to Andrew Logan, a leading oil and gas analyst. Yet Americans are unhappy with record high gas prices, and the U.S. public has become very welcoming of alternative energies and energy-saving technologies in recent years.. (Herbst, 2007).

Hybrid and "flex-fuel" vehicles are becoming popular not only because of consumers' demand for them, but also because of automakers taking advantage of fuel-efficiency calculation loopholes. Automakers are able to account for potential use of alternative fuels, particularly ethanol, in "flex-fuel" vehicles, even if alternative fuels are not available in the area or if owners use traditional fossil fuels. Gasoline-electric hybrid vehicles are more generally more fuel efficient than gasoline-only models.

The President's 2007 budget request included $150 million for bio-mass and bio-refinery systems research and development, an increase of $59 million from the 2006 level (Budget Function 270, 2007). Bio-refining technologies are becoming a reality in the United States and are receiving increasing funding from Congress.

Keeping troops safe from attacks is a military objective. If these efforts are tied to support for bio-fuels and elimination of field waste, the case for development of such technologies is strengthened. One possible argument against burning trash versus traditional fossil fuels is a slight increase in NOX, which are believed to contribute to acid rain, ozone depletion, and aggravation of asthmatic conditions, among other problems (EPA, 1998). However, the high-temperature refining process can reduce these dangerous compounds to their elemental nitrogen and oxygen. The reduction in carbon-dioxide, particulate matter, and other pollutants, when compared to fossil fuels, makes bio-refineries a cleaner way to produce electricity.

Trashing another country's land with the garbage of an expeditionary army is not politically popular overseas. Spending American taxpayers' money purchasing fuel from

foreign companies is not politically popular at home. Politically, tactical bio-refineries could provide “green” energy, keep our troops safer, provide our hosts with a cleaner American footprint, reduce fuel payments to foreign companies, and improve our responsiveness to natural disasters at home and abroad. Recent administrations have had troubles with all of those issues in the past. Tactical bio-refineries could be a step in the right direction politically.

B. THE POSSIBILITY OF ADJUSTING STANDARD FUEL PRICES TO INCLUDE END-TO-END FUEL DELIVERY COSTS

Adjusting the standard fuel price to cover all end-to-end costs has several problems. The standard fuel price is an average of fuels provided by DESC. These fuels are not provided in equal proportions. An increase in the standard fuel price would require increasing the price of individual fuels significantly or raising the cost of all fuels. The market economics of supply and demand might provide the intended results of meeting total costs by reducing demand, but may create inefficiencies and chokepoints in the logistics stream by disrupting expected fuel amounts and established patterns of use.

Transportation costs of fuels vary according to customer and use. A Navy destroyer receiving fuel at the DESC, Bahrain station would have few transportation costs relative to an Army unit deployed deep inside Iraq or Afghanistan. If DESC fuel pricing included aggregate end-to-end costs, the Navy would, in effect, be providing a subsidy to the Army to cover its fuel transportation costs. While military “jointness” is encouraged in an operational environment, service parochialism still leads the way with regard to budgetary commingling. Setting separate fuel prices based on the customer, usage, distance to travel, and other cost variables is impractical and would be very difficult to accurately calculate or forecast (DESC, 2006).

VII. CONCLUSIONS AND RECOMMENDATIONS

A. DOMESTIC INSTALLATION RESULTS: THE RETURN ON INVESTMENT (ROI) OF ENERGY SAVINGS PERFORMANCE CONTRACTS (ESPCs)

Based on government Super-ESPC data from FY1998 to FY2007, investment in installation energy efficiency is projected to produce energy savings in excess of investment cost. Figure 18, a regression of utility savings versus project investment, suggests that for every dollar invested in project improvement, 2.23 dollars in utility costs are saved over the course of an ESPC project lifetime. According to data provided by the Department of Energy, of the $2.68 billion in forecasted energy savings, $2.65 billion is contracted to be transferred to private capital sources, with the remaining $27 million in savings provided to government agencies (difference due to rounding). The total invested by private equity for facility energy efficiency is $1.09 billion. Due to positive net present values, government agencies are financially better off with ESPCs than without them for projects that are not funded by direct appropriations. If the government could replicate the forecasted savings, availability of capital, and program management of private equity contracts, it could reduce its energy expenditures by a greater degree than with ESPCs. Table 10 provides returns on investment per year for private equity investments in government agency installation energy efficiency and potential government returns for self-investment in energy efficiency.

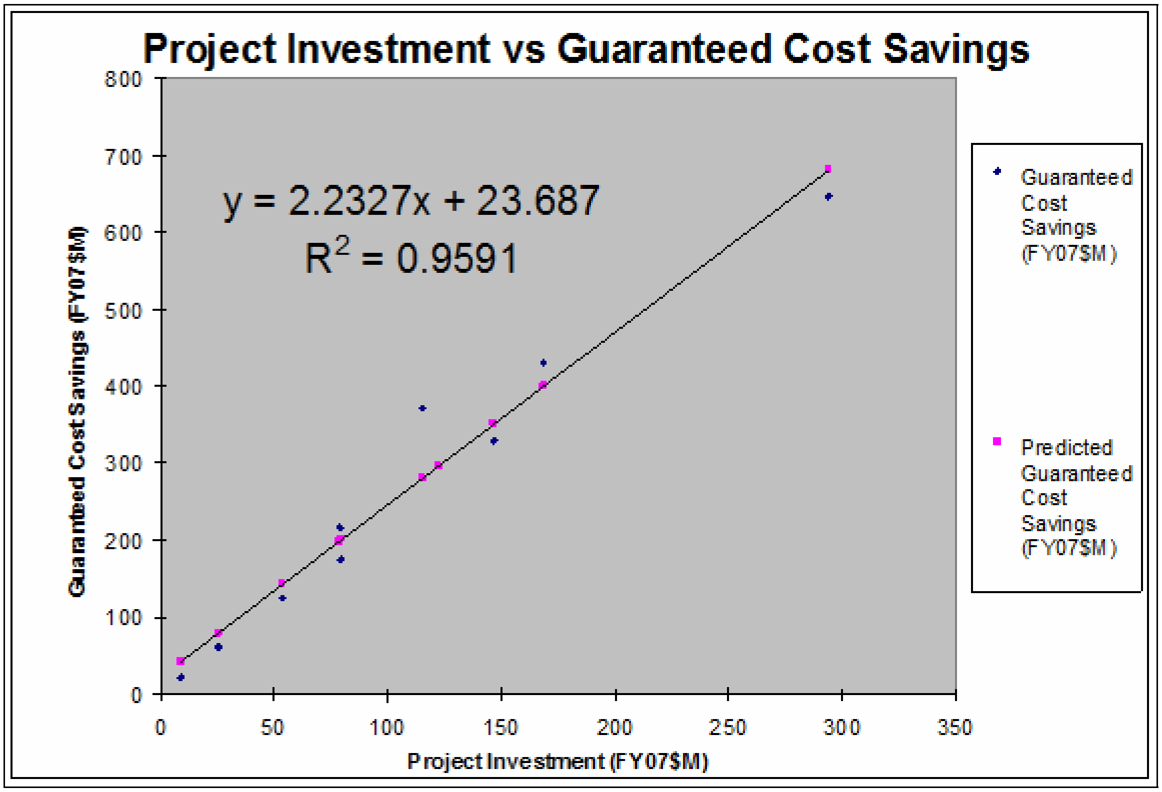

Figure 18. Super ESPC Project Investment versus Guaranteed Savings [After: www1.eere.energy.gov]

All $ figures in FY07$M	Project Investment	Contract Price	Guaranteed Cost Savings	Contractor Net	Contractor ROI	Govt Net (w/contract)	Govt Net (self invest)	Govt ROI (self invest)
Total for FY 1998	9	20	23	11	127%	3	14	160%
Total for FY 1999	53	123	125	70	131%	1	71	133%
Total for FY 2000	80	174	175	94	119%	1	96	120%
Total for FY 2001	147	335	330	188	128%	-4	183	125%
Total for FY 2002	115	373	373	257	224%	1	258	224%
Total for FY 2003	294	635	647	341	116%	12	352	120%
Total for FY 2004	25	59	62	34	134%	3	37	146%
Total for FY 2005	79	217	217	138	175%	0	138	176%
Total for FY 2006	169	425	430	256	151%	5	261	155%
Total for FY 2007	122	291	296	169	138%	4	173	142%
Total all years	1,093	2,651	2,678	1,558	143%	27	1,585	145%

Project Investment: Amount invested in facility improvements
Contract Price: Contract cost to government
Guaranteed Cost Savings: Reduction in energy/utility costs over length of contract
Contractor Net: Difference between contract price and project investment
Contractor ROI: Contractor return on investment (contractor net divided by project investment)
Govt net (w/contract): Guaranteed cost savings less contract price
Govt net (self invest); Guaranteed cost savings less project investment
Govt (self invest) ROI: Govt net (self invest) divided by project investment

Table 10. All Government Super ESPC Data FY98-07 [After: www1.eere.energy.gov, 2007]

Mandates to reduce energy consumption are a strong catalyst for improvement in installation energy efficient projects. Limited appropriated funding precludes many government agencies from funding their own energy efficient projects. ESPCs that increase fuel efficiency contribute to government agency efforts to comply with executive orders and other federal energy efficiency mandates. Noncompliance with theses mandates could incur negative budgetary or other policy ramifications.

B. THE VALUE OF ENERGY AUDITS IN DETERMINING THE POTENTIAL FOR INVESTMENT IN ENERGY EFFICIENCY PROJECTS

This research discussed the role that energy audits play in determining the most effective use of investment dollars for domestic installation energy efficiency projects. First, some background on DoD energy usage and spending was provided. Next, an energy audit was defined followed by a discussion of military facility energy audit requirements. The three major types of energy audits were described with an explanation of energy conservation versus efficiency and methods for determining project cost effectiveness. An overview of EO 13423 illustrated mandated energy reduction requirements. Finally, conclusions regarding the continued use of energy audits at government installations were presented.

The energy audit is a valuable first step in assessing economically viable energy efficiency projects. Through sound investment in energy efficiency, adherence to the laws requiring reductions in government installation energy intensity and emissions can be funded by reductions in utility expenditures. The reduced financial and environmental costs will allow the government to provide its citizenry with slightly reduced operating expenses and a cleaner environment.

C. DEPLOYED INSTALLATION RESULTS: THE VALUE OF A TACTICAL GARBAGE-TO-ENERGY REFINERY (TGER) AT FORWARD OPERATING BASES

Tactical bio-refineries address a present and recurring need in military operations. The United States Army and Marine Corps have expressed a consistent interest in this technology. Research and development efforts have produced a product that exceeds the

established requirements. If the TGER program continues to meet cost, schedule, and performance requirements, it has the potential for widespread dissemination and could provide a great service to the troops deployed in forward operating bases.

Benefits of reducing fuel demand at remote locations include multiplicative saving effects on service fuel transportation costs in terms of dollars as indicated in Table 11 and immeasurable benefits from possible reductions in casualties. Fuel efficiency in deployed support equipment, vehicles, and bases frees scarce fuel resources to be used in higher priority, higher risk operating activities. Technologies that offer fuel savings should not be considered on the basis of the financial benefit of the fuel offset they provide, but rather on the total savings provided to the logistics system as a result of that fuel offset. Including system-wide fuel delivery costs changes the ROI and payback calculations compared to unburdened savings. Table 12 provides ROI calculations for unburdened fuel and waste savings and three burdened fuel and waste cost estimates based on TGER life expectancy. Like most equipment, the longer a TGER device will last, the greater its return on investment. Figure 19 shows payback periods for a $1.3 million TGER by cost saving elements of burdened and unburdened fuel and waste.

	Burdened Cost of Fuel	Burdened Cost of Waste Disposal
OSD (PA&E) Study	$5.54/gal	-
LMI Study	$20/gal	$975/ton
SMP Model	$6.40/gal	-

Table 11. Summary of Delivered Fuel and Waste Disposal Cost Estimates

All dollar figures in FY07K$										
Time Period (Years)	1	2	3	4	5	6	7	8	9	10
Investment (initial cost difference)	1,275									
Cumulative LMI Operating Savings	1,284	2,569	3,853	5,137	6,422	7,706	8,990	10,275	11,559	12,843
LMI Model ROI	1%	101%	202%	303%	404%	504%	605%	706%	807%	907%
Cumulative SMP Operating Savings	269	537	806	1,075	1,343	1,612	1,880	2,149	2,418	2,686
SMP Model ROI	-79%	-58%	-37%	-16%	5%	26%	47%	69%	90%	111%
Cumulative OSD Operating Savings	233	465	698	930	1,163	1,395	1,628	1,860	2,093	2,325
OSD Model ROI	-82%	-64%	-45%	-27%	-9%	9%	28%	46%	64%	82%
Cumulative Unburdened Operating Savings	90	180	269	359	449	539	629	719	808	898
Unburdened ROI	-93%	-86%	-79%	-72%	-65%	-58%	-51%	-44%	-37%	-30%

Table 12. Cumulative Operating Savings and Comparative ROIs (TGER @ $1.3)

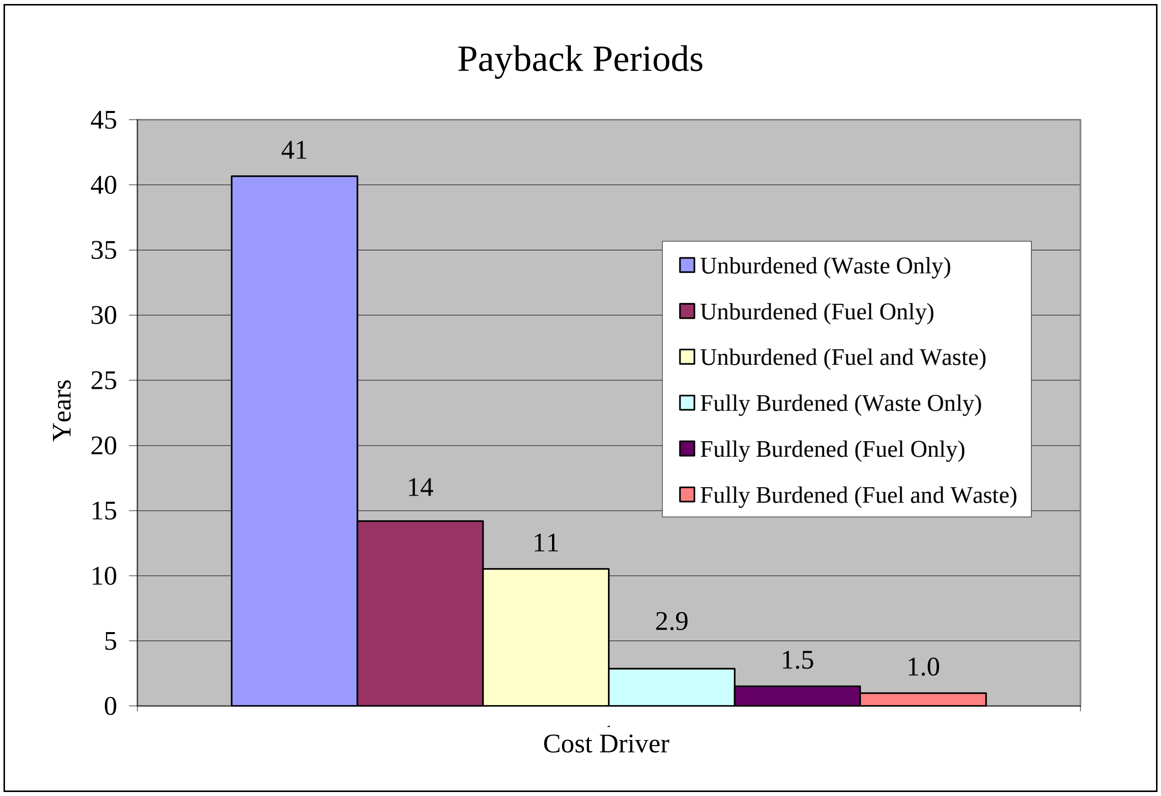

Figure 19. TGER Payback Periods ($1.3M initial cost)

D. WHO SHOULD PAY FOR INVESTMENT IN FUEL EFFICIENCY?

Due to the difficulties in obtaining proper reimbursement for end-to-end costs of fuel delivery and its requirement to remain solvent as part of Working Capital Fund, Defense-Wide, it is not in the interest of DESC to pay for fuel delivery according to service-specific requirements. If cost savings are to be realized through the use of energy-efficient systems and energy-replacing systems, those savings will be realized by the individual services. Therefore, those services poised to realize the transportation savings have an incentive to incorporate energy efficiencies into their war-fighting operations. The extent to which these savings are distributed among support or O&M accounts should be dependent on the willingness of each accounts' beneficiaries to invest in efficiency-producing services, practices, or goods.

E. RECOMMENDED AREAS FOR FURTHER RESEARCH

Possible areas for additional study that supplement this research include:

- How the Tactical Garbage-to-Energy Refinery is progressing in the military acquisition process
- How to create fuel efficiency financial incentives for military commanders
- Comparing returns and risks of private ESPC investment to other market investments
- Variability of fuel logistics costs in the military logistics system
- Comparing projected and actual utility savings

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